Atlas Digital Amplifier
User's Manual

Performance Motion Devices, Inc.
80 Central Street
Boxborough, MA 01719

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Related Documents

Atlas Digital Amplifier Complete Technical Reference

Complete electrical and mechanical description of the Atlas Digital Amplifier with detailed theory of operations.

Magellan Motion Processor User's Guide

Complete description of the Magellan Motion Processor features and functions with detailed theory of operations.

Magellan Motion Processor Developer's Kit Manual

How to install and configure the DK58000 series and DK55000 series developer's kit PC board.

Pro-Motion User's Guide

User's guide to Pro-Motion, the easy-to-use motion system development tool and performance optimizer. Pro-Motion is a sophisticated, easy-to-use program which allows all motion parameters to be set and/or viewed, and allows all features to be exercised.

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1. Introduction

In This Chapter

- Atlas Digital Amplifier Overview
- Features and Functions
- Atlas Model Numbering
- Atlas Developer's Kits

1.1 Atlas Digital Amplifier Overview

Atlas Digital Amplifiers are single-axis amplifiers that provide high performance torque control of brushless DC, step motor, and DC brush motors. They accept digital torque commands from an external source and are used directly for motor torque control applications, or in conjunction with higher level controllers for velocity or positioning applications. Their very compact size and high power output make them an ideal solution for single-card machine controllers that require high performance in a small envelope.

Atlas digital amplifiers provide many advanced control features including user-programmable gain parameters, performance trace, field oriented control, and I^2t current management. Atlas amplifiers are powered from a single supply voltage, and provide automatic protection from overcurrent, undervoltage, overvoltage, overtemperature, and short circuit faults.

The Atlas family has been designed to work seamlessly with PMD's Magellan family of motion processor ICs. Alternatively, they can be used with dedicated FPGAs, digital signal processors, or general purpose microprocessors. Communication to/from Atlas amplifiers is via SPI (Serial Peripheral Interface) using a simple, packet-oriented protocol. For step motors, in addition to the SPI format a dedicated pulse & direction input mode is provided.

Atlas amplifiers are packaged in a compact solderable module and utilize standard through-hole pins for all connections. They are provided in both vertical and horizontal mounting configurations, and with and without heat sink attachment tabs.

This manual provides a description of the electrical and mechanical specifications for the Atlas Digital Amplifiers, along with a summary of its operational features. For complete documentation on all aspects of the Atlas Digital Amplifier including a programmers command reference, refer to *Atlas Digital Amplifier Complete Technical Reference*. For more information on the Magellan Motion Processor IC, consult the *Magellan Motion Processor User's Guide*.

1.2 Features and Functions

The Atlas family of amplifiers provide an extensive list of functions, including:

- Supports Brushless DC, DC Brush, and Step Motors
- High performance all-digital power amplifier
- Works with Magellan ICs, FPGAs or microprocessor-based controllers
- SPI interface eliminates analog +/- 10V signals

- Rugged solderable format uses standard through-hole pins
- Total power output to 1Kilowatt
- Very compact size 1.5" x 1.5" x 0.6"
- Comes in horizontal and vertical mount configurations
- Available with rugged mechanical tab mounts
- Supply voltage range of 12V to 56V
- High current output to 14A continuous, 25A peak
- Digital current loop with choice of standard A/B or Field Oriented Control (FOC)
- Direct signal pulse and direction input
- I^2t current foldback limiting
- Selectable 20 kHz, 40 kHz, and 80 kHz PWM rate
- Overcurrent, overvoltage, undervoltage, overtemperature, and watchdog timeout protection
- Single supply operation.
- Enable input and FaultOut output safety interlock signals
- 8 MHz SPI (Serial Peripheral Interface) communication
- Performance trace of up to 1,020 words and four simultaneous variables
- 1,024 word non-volatile parameter storage
- Microstepping control with up to 256 microsteps per full step
- Signal conditioning buffers and analog filters on all I/O signals
- High performance microprocessor-style command interface
- Fully RoHS compliant and CE marked

1.3 Atlas Model Numbering

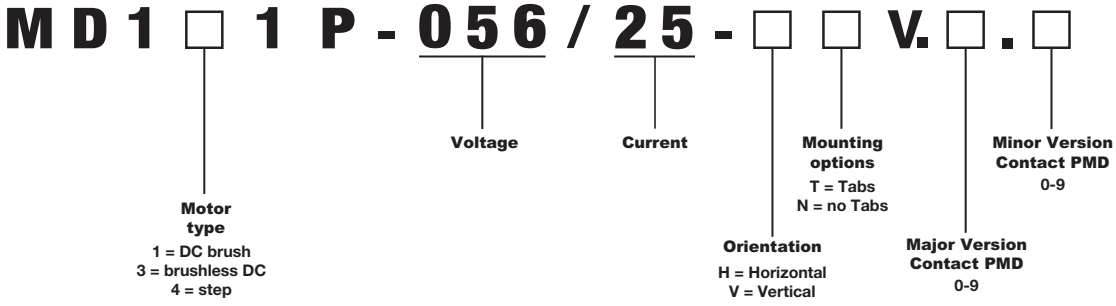

Figure 1-1: Atlas Model Numbering

Atlas units are provided in three different motor types (DC brush, brushless DC, and step) with the choice of two mounting orientations (vertical and horizontal), and the choice of tab or no tab mounting hardware slots. This is a total of twelve different versions in all.

1.3.1 Atlas Model Number Examples

Part Number	Motor Type	Mounting Orientation	Tab/No Tab
MD131P-56/25-VT	Brushless DC	vertical	tabs
MD111P-56/25-HN	DC brush	horizontal	no tabs
MD141P-56/25-VT	step motor	vertical	tabs

1.4 Atlas Developer's Kit

To simplify development, an Atlas Developer's Kit is available, shown in Figure 1-2.

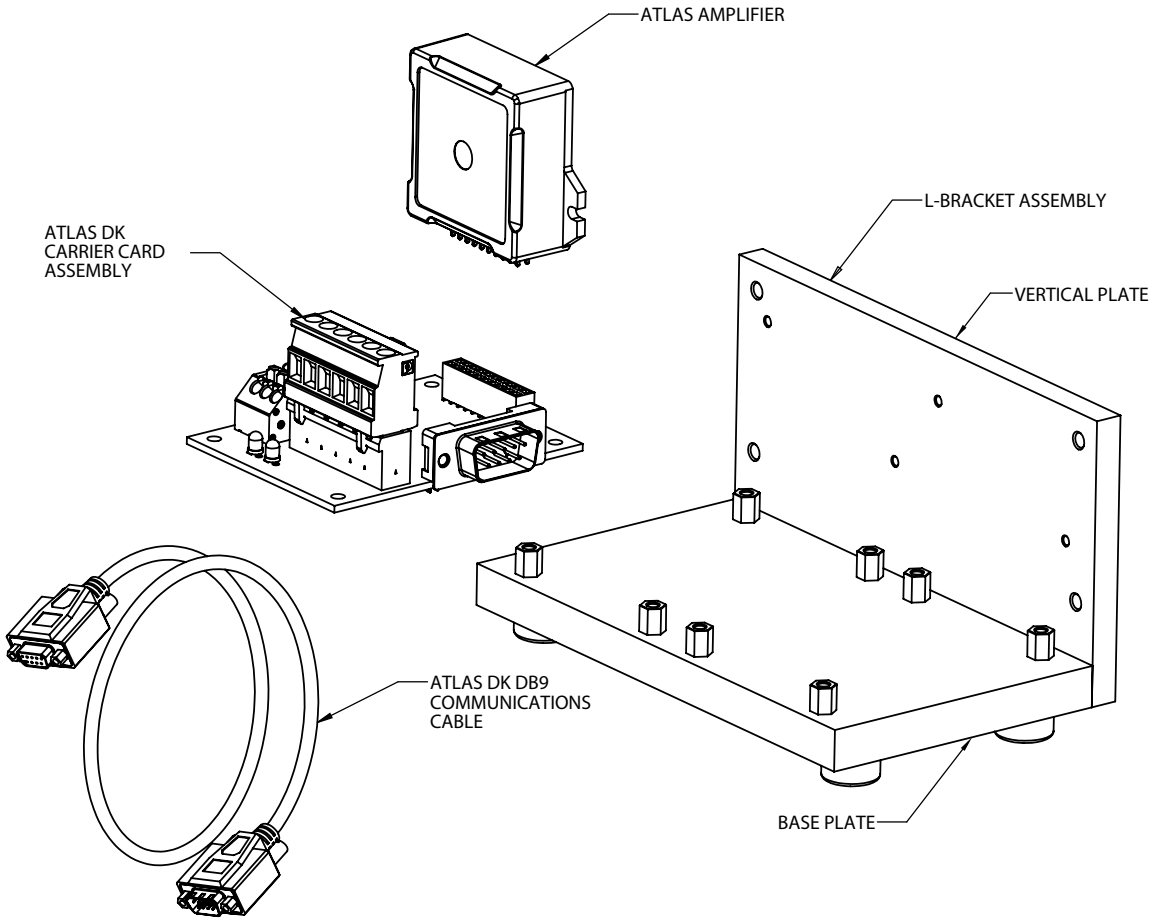

Figure 1-2: Developer Kit Components

The following software and hardware components are included in every Atlas Developer's Kit:

- Pro-Motion CD and User's Guide
- C-Motion and VB-Motion SDK CD, including PDFs of all Atlas documentation
- Atlas DK DB9 communications cable

For the following components, you will provide information that will specify how you want the DK tailored for your exact development needs:

- Specific Atlas units to be included
- Atlas carrier card (horizontal and vertical versions)
- L-bracket base with optional vertical plate for heat sink attachment(comes in 1, 2, or 4 axis version)

The L-bracket is optional but highly recommended because it provides a stable mechanical base from which you can conveniently connect and operate your prototype system motors. With the vertical plate option selected, the Atlas units have additional heat sinking, which can be extended further by connecting the vertical plate to your own heat sink or cold plate.

Electrical connections to the Atlas DK carrier cards are made by DB9 connector, and by jack screw connectors. Designers who plan to use the Atlas in conjunction with PMD's Magellan Motion Processor can connect the Atlas DK to the Magellan DK card, purchased separately. For more information on this product see the *Magellan Motion Processor Developers Kit Manual*.

Refer to Appendix A, "Atlas Developer's Kit" for complete information on setting up and operating the Atlas DK.

1.4.1 Atlas Developer's Kit Part Number

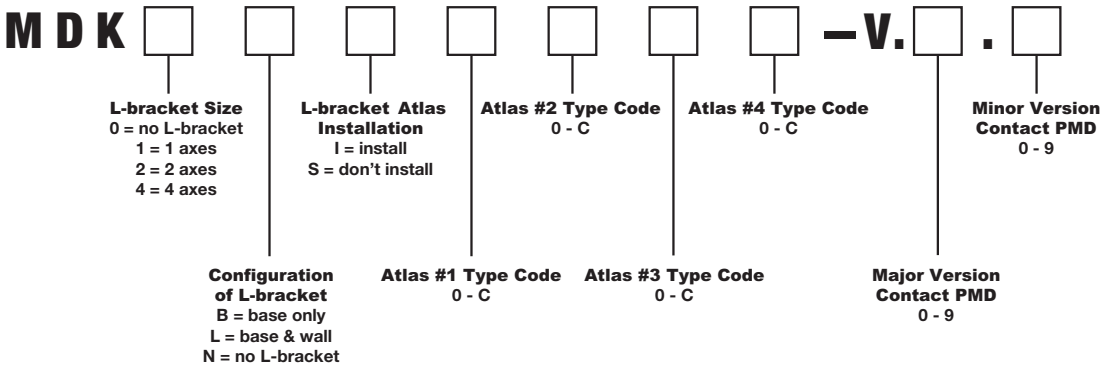

Figure 1-3: Developer Kit Numbering

Atlas Type Codes

0 = None	4 = Brushless DC, Vertical, no tabs	8 = DC Brush, Horizontal, tabs	C = Step motor, Horizontal, no tabs
1 = Brushless DC, Vertical, tabs	5 = DC Brush, Vertical, no tabs	9 = Step motor, Horizontal, tabs	
2 = DC Brush, Vertical, tabs	6 = Step motor, Vertical, no tabs	A = Brushless DC, Horizontal, no tabs	
3 = Step motor, Vertical, tabs	7 = Brushless DC, Horizontal, tabs	B = DC Brush, Horizontal, no tabs	

Atlas units to be included with the DK are specified via an 'Atlas Type Code' as shown in Figure 1-3. Each of twelve possible Atlas types are specified via a letter code 1-C. A zero (0) code indicates no Atlas. Note that there is no requirement for the Atlas units to be the same type.

Horizontal Atlas units are provided with a horizontal version of the carrier card, and vertical Atlas units are provided with a vertical version of the carrier card.

The L-bracket is specified by size (1, 2, or 4 Atlas carrier card mounting slots), the hardware configuration (no L-bracket, base only, base & vertical wall), and whether or not PMD should install the Atlas units and carrier cards on the L-bracket.

If no L-bracket is specified then each Atlas will be provided with a carrier card only.

1.4.2 Atlas DK Part Number Examples

Part Number	Atlas Units	L-Bracket/Carrier Contents
MDK4LI7777	Four Brushless DC, horizontal package, with tabs	4-axis L bracket (base & wall) with all four Atlas units installed on the L-bracket
MDK0NS3990	One step motor, vertical package, with tabs Two step motor, horizontal package, with tabs	No L-bracket, one vertical DK carrier and two horizontal Atlas carriers.
MDK2BI8800	Two DC Brush, horizontal package, with tabs	2-axis L-bracket (base only) with both Atlas units installed on the L-bracket

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2. Functional Characteristics

2

In This Chapter

- Operational Specifications
- Physical Characteristics & Mounting Dimensions
- Mounting Options

2.1 Operational Specifications

Motor types supported:	Brushless DC, DC Servo, Step Motor
Communication format:	SPI (Serial Peripheral Interface)
SPI clock frequency range:	up to 8.0 MHz
Torque command rate:	up to 10.0 kHz
Current measurement resolution:	12 bits
Current loop type:	P, I (proportional, integral) with Integral limit
Current loop resolution:	16 bits
Current loop rate:	19.530 kHz
Current loop modes:	individual phase, field oriented control, third leg floating
Safety functions:	over current detect, programmable over temperature detect, programmable overvoltage detect, programmable under voltage detect, programmable I^2t current foldback, watchdog timeout
Output limiting:	programmable energy, current, and voltage limit
Command modes:	SPI voltage, SPI torque, pulse & direction signal
PWM rate:	20 kHz, 40 kHz, or 80 kHz
PWM generation modes:	sinusoidal, space vector modulation, standard single-phase
Pulse & direction rate:	1.0 M Pulses/sec
Microsteps per full step:	up 256 per full step
Trace capture modes:	one time, rolling-buffer mode
Trace trigger modes:	internal, external by controller
Trace buffer size:	1,020 16-bit words
NVRAM storage size:	1,024 16-bit words
Number of traceable variables:	35
Number of commands:	68

2.2 Physical Characteristics & Mounting Dimensions

2.2.1 Vertical Unit, With Tabs

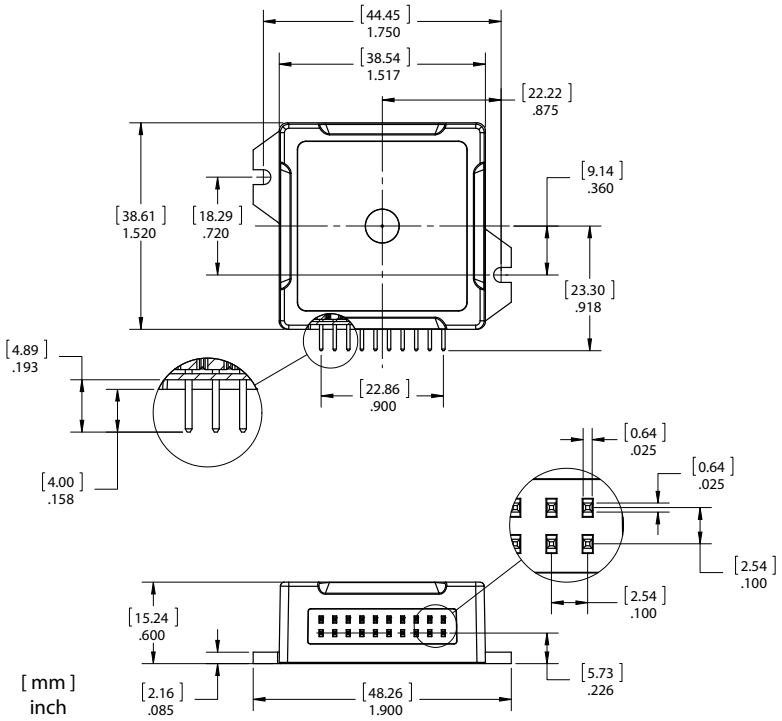


Figure 2-1: Physical Characteristics - Vertical w/Tabs

2.2.2 Vertical Unit, Without Tabs

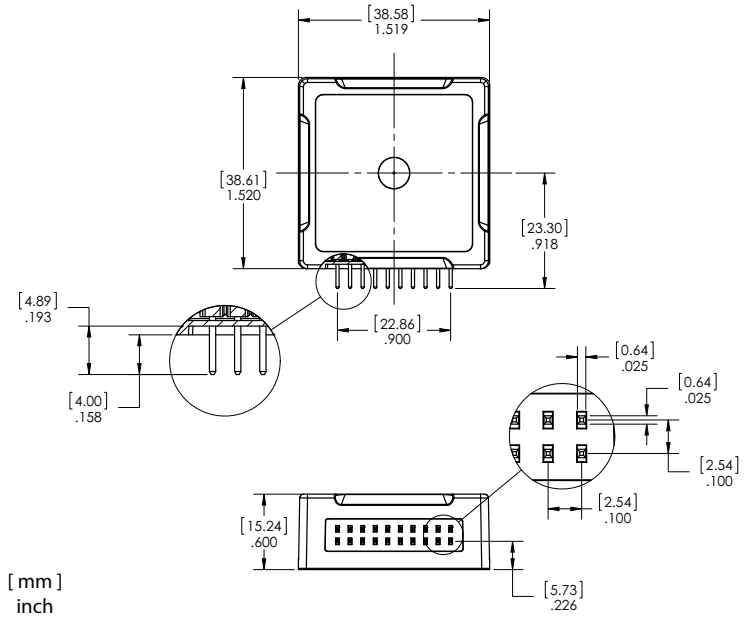


Figure 2-2: Physical Characteristics - Vertical w/o Tabs

2.2.3 Horizontal Unit, With Tabs

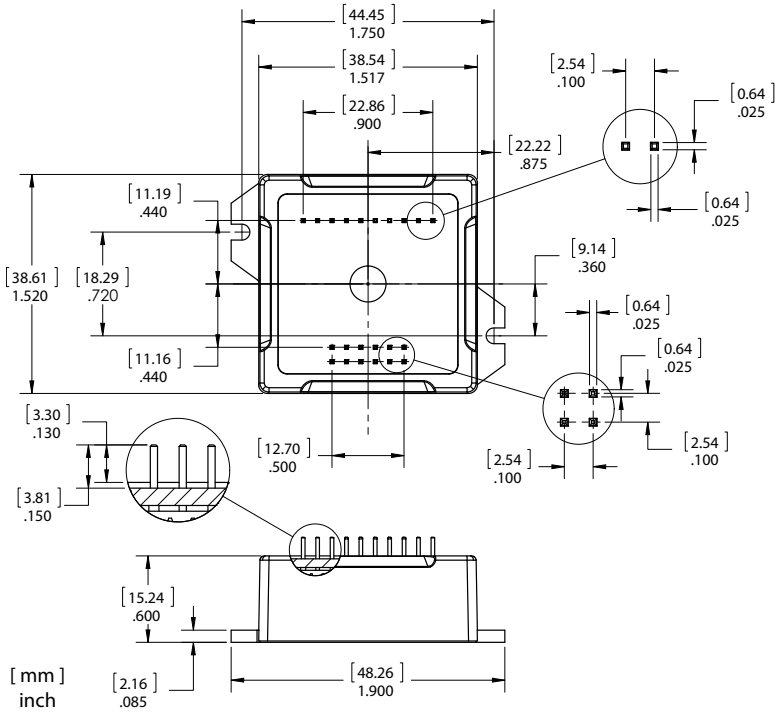


Figure 2-3: Physical Characteristics - Horizontal w/Tabs

2.2.4 Horizontal Unit, Without Tabs

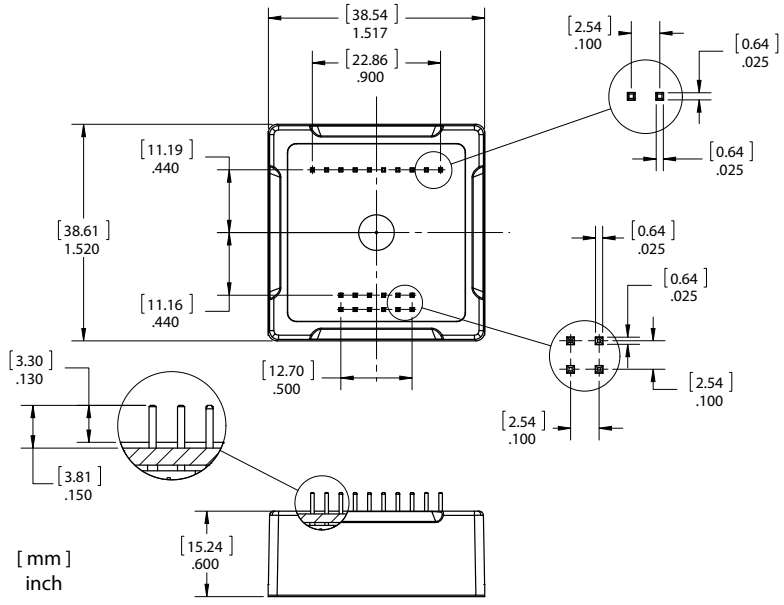
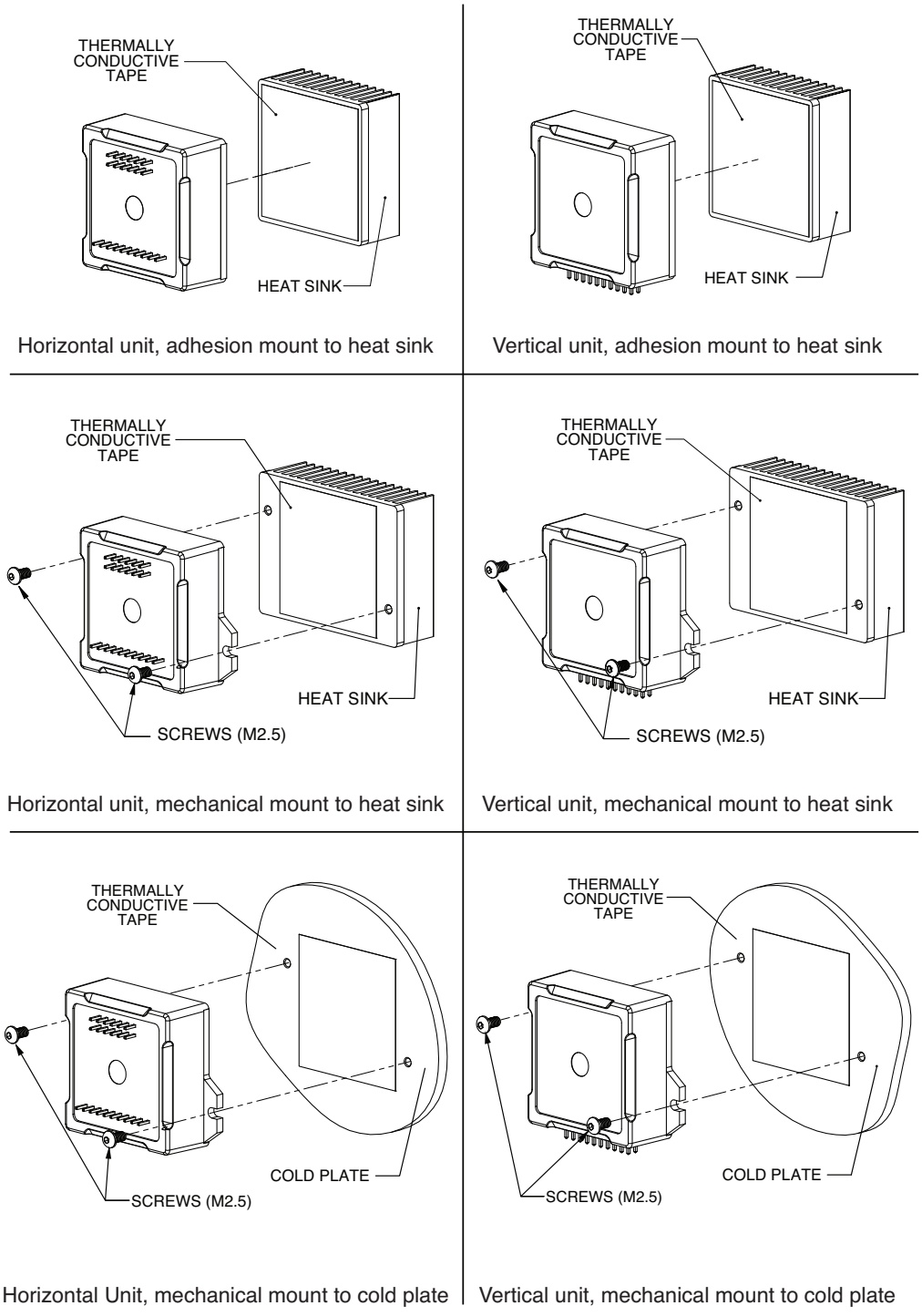


Figure 2-4: Physical Characteristics - Horizontal w/o Tabs

2.3 Mounting Options

Atlas amplifiers are provided in two separate mounting configurations; vertical and horizontal. In addition, they are available with hardware attachment tabs, and without. There are a number of mounting options when the Atlas is used with additional heat sinking, as shown in Figure 2-5. Note that all Atlas amplifiers, no matter how they are mounted, should be soldered onto the PC board in the production application.

Figure 2-5: Horizontal & Vertical Unit Mounting Options



3. Electrical Specifications

In This Chapter

- Drive Ratings
- Absolute Maximum Ratings
- Environmental Ratings
- Safety and Compliance
- DC Characteristics
- Pin Descriptions and Pinouts
- Signal Interfacing
- Connection Overview

3.1 Drive Ratings

Specifications*	DC Brush Motor	Brushless DC Motor	Step Motor
Nominal supply voltage	12-56 VDC	12-56 VDC	12-56 VDC
Continuous current	14.0 ADC	10.0 Arms	9.0 Arms
Peak current (per phase)	25.0 A	25.0 A	25.0 A
Maximum continuous power	670 W	590 W	610 W

* transformer isolated power supply, T < 40° C

A coldplate or a heatsink in an environment with sufficient airflow can be used to achieve the above drive ratings.

For temperature operation beyond the standard 0-40° C range, above-listed ratings may change. Contact your PMD representative for additional information on Atlas extended temperature operation including higher temperature drive ratings.

3.2 Absolute Maximum Ratings

Parameter	Rating
HV voltage range	0 V to +60 V
~Enable voltage range	-10 V to +24 V
SPISI, SPIClk, ~SPICS voltage range	-0.5 V to 6.5 V
SPISO voltage range	-0.5 V to 3.7 V
FaultOut voltage range	-0.3 V to 24 V
FaultOut output current	-35 uA to 50 mA
5V output current	100 mA

All voltage values are with respect to GND unless otherwise noted.

3.3 Environmental Ratings

Specification	Value
Operating ambient temperature	0 to 40 C
Maximum base plate temperature	75 C
Storage temperature	-20 to 85 C
Reflow soldering temperature	300 C (1.5mm for 10 seconds)
Humidity	0 to 95%, non-condensing
Altitude	Up to 2,000 meters without derating
Contamination	Pollution Degree 2

3.4 Safety and Compliance

Specification	Standard
CE	LVD: EN60204-1 EMC-D: EN61000-6-1, EN61000-6-3, EN55011
Electrical safety	Designed to UL508C, UL840 and EN60204-1
Hazardous materials	RoHS compliant
Flammability	UL94-V2 or V0
Enclosure	IP20

3.5 DC Characteristics

3.5.1 SPISI, SPIClk

Schmitt-trigger Input	Min	Max	Conditions
V_+, Positive-going input threshold voltage	1.6 V	2.0 V	
V-, Negative-going input threshold voltage	0.9 V	1.2 V	
VT, Hysteresis V+-V-	0.6 V	1.0 V	
I_{IN}, input current		±1 uA	Input voltage is 5.5 V or GND

3.5.2 SPISO

	Min	Max	Conditions
V_O, output voltage	0	3.3 V	
V_{OH}, Logic 1 output voltage	3.2 V		I_{OH}=-100 uA
	2.4 V		I_{OH}=-16 mA
V_{OL}, Logic 0 output voltage		0.1 V	I_{OL}=100 uA
		0.7 V	I_{OL}=16 mA
I_{OZ}, input current when ~SPICS is "1"		10 uA	V_O = 0 to 3.7 V

3.5.3 ~SPICS

	Min	TYP	Max	Conditions
V_{IH}, Logic 1 input voltage	2 V			
V_{IL}, Logic 0 input voltage			0.8 V	
I_{IN}, pull-up current		-500 uA		

3.5.4 ~Enable

Schmitt-trigger input	Min	Max	Conditions
V_+, Positive-going input threshold voltage	1.6 V	2.0 V	
V-, Negative-going input threshold voltage	0.9 V	1.2 V	
VT, Hysteresis V+-V-	0.6 V	1.0 V	

3.5.5 FaultOut

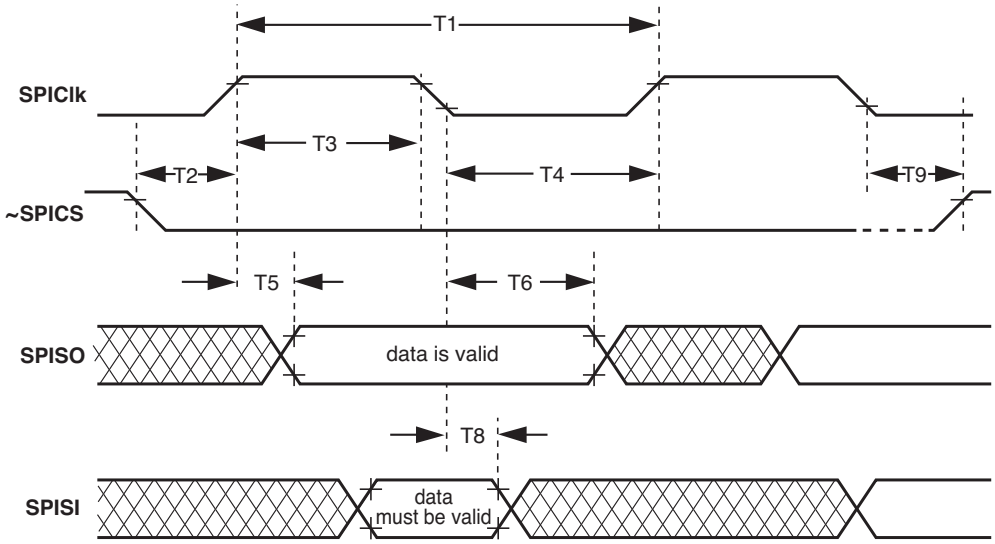
	Min	Max	Conditions
Output impedance with Logic 1 output	148 Kohm	152 Kohm	I_{OH}=-100 uA
V_{OL}, Logic 0 output voltage		0.25 V	I_{OL}=10 mA

3.5.6 5V

	Min	Max	Conditions
Voltage tolerance	-5%	5%	Output current 0~100 mA
Short circuit protection	Not available		

3.6 AC Characteristics

Figure 3-1: Timing Diagrams



See Figure 3-1 for timing numbers.

Timing Interval	No.	Min	Max
T_{SPI}, SPI clock cycle time	T1	125 nsec	
Pulse duration, SPIClk high	T3	(0.5 T_{SPI}-10) nsec	
Pulse duration, SPIClk low	T4	(0.5 T_{SPI}-10) nsec	
SPIClk high to SPISO valid delay time	T5		30 nsec
SPISO date valid time after SPIClk low	T6	(0.75 T_{SPI}+2.2) nsec	
SPISI setup time before SPIClk low	T7	30 nsec	
SPISI valid time after SPIClk low	T8	(0.5 T_{SPI}-6) nsec	
~SPICS low to first SPIClk high	T2	400 nsec	
Last SPIClk low to ~SPICS high	T9	0.5 T_{SPI}	

3.7 Pin Descriptions and Pinouts

3.7.1 Pinouts, Atlas Vertical Unit

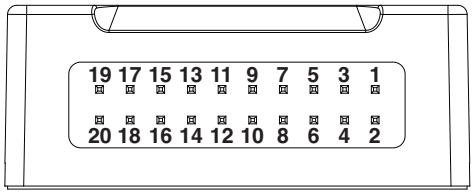


Figure 3-2: Vertical Unit Pinouts

Pin	Name	Pin	Name
1	Pwr_Gnd	2	Pwr_Gnd
3	HV	4	HV
5	Motor A	6	Motor A
7	Motor B	8	Motor B
9	Motor C	10	Motor C
11	Motor D	12	Motor D
13	~Enable	14	FaultOut
15	5V	16	GND
17	~SPICS/AtRest	18	SPISI/Direction
19	SPIClk/Pulse	20	SPISO

The pins are 0.1 inch spacing and 0.025inch pin width.

3.7.2 Pinouts, Atlas Horizontal Unit

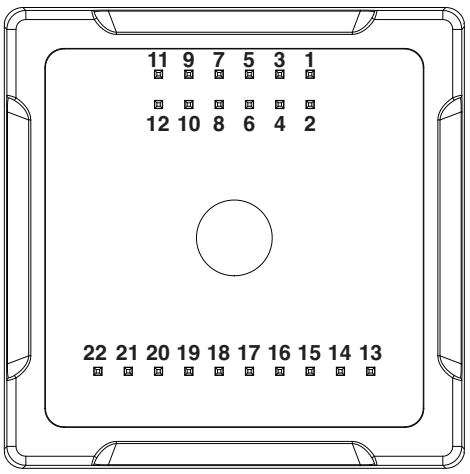


Figure 3-3: Horizontal Unit Pinouts

Pin	Name	Pin	Name
1	Motor D	2	Motor D
3	Motor C	4	Motor C
5	Motor B	6	Motor B

Pin	Name	Pin	Name
7	Motor A	8	Motor A
9	HV	10	HV
11	Pwr_Gnd	12	Pwr_Gnd
13	5V	14	GND
15	~Enable	16	FaultOut
17	GND	18	~SPICS/AtRest
19	SPISO	20	SPISI/Direction
21	SPIClk/Pulse	22	GND

The pins are 0.1 inch spacing and 0.025inch pin width.

3.7.3 Pin Descriptions

Pin Name	Direction	Description
HV		DC power to Atlas module, referenced to Pwr_Gnd. The DC power source should be a transformer isolated power supply. Two Atlas pins carry this signal, so care should be taken to connect both pins.
Pwr_Gnd		Power return for HV, Motor A, Motor B, Motor C and Motor D. Two Atlas pins carry this signal, so care should be taken to connect both pins.
Motor A		Motor output pin A. Used with Brushless DC, DC Brush, and Step Motors. Two Atlas pins carry this signal, so care should be taken to connect both pins.
Motor B		Motor output pin B. Used with Brushless DC, DC Brush, and Step Motors. Two Atlas pins carry this signal, so care should be taken to connect both pins.
Motor C		Motor output pin C. Used with Brushless DC, and Step Motors. Two Atlas pins carry this signal, so care should be taken to connect both pins.
Motor D		Motor output pin D. Used with Step Motors. Two Atlas pins carry this signal, so care should be taken to connect both pins.
~Enable	Input	~Enable is an active-low input. Should be tied or driven low for Atlas motor output to be active.
FaultOut	Output	FaultOut is high impedance when active. It provides programmable fault indication, and is low when inactive.
SPIClk/Pulse	Input	SPI input clock or Pulse signal. Pulse is used when Atlas is set to pulse & direction signal mode, and causes a position change command upon a high to low transition. Selection of signal interpretation for this pin is via the SPI communications bus. The default signal interpretation is SPIClk.
SPISO	Output	SPI data master in slave out signal. It goes to high impedance when ~SPICS is high. This pin is not used if Atlas is operating in pulse & direction signal mode.
SPISI/Direction	Input	SPI data master out slave in signal or Direction signal. Direction is used when Atlas is set to pulse & direction signal mode, and indicates the step direction. Low means the position decreases upon a high to low transition of the Pulse signal, and high means the position increases. Selection of signal interpretation for this pin is via the SPI communications bus. The default signal interpretation is SPISI.
~SPICS/AtRest	Input	~SPICS signal or AtRest signal. ~SPICS enables SPI communication when transitioning low. The SPI block is disabled when ~SPICS is high. *AtRest* is used when Atlas is set to pulse & direction signal mode, and indicates that the step motor holding current should be used rather than the drive current. Selection of signal interpretation for this pin is via the SPI communications bus. The default signal interpretation is ~SPICS.

Pin Name	Direction	Description
GND		Ground return for ~Enable, FaultOut, SPI or pulse & direction signals and 5V.
5V		5V output used to drive external circuitry. Maximum output current is 100 mA.

3.8 Signal Interfacing

3.8.1 ~Enable

~Enable and FaultOut signals are typically used to implement a safety interlock between the Atlas module and other portions of the system.

~Enable is an active low input that must be tied or driven low for the Atlas power output to be active. Its input buffer is shown in Figure 3-4. The circuit accepts signals in the range of 0-24V and has TTL compatible, Schmidt trigger thresholds. It has a pull-up to 5V to allow direct interfacing to open collector enable sources without external pull-up resistor and a 1.3kHz R-C low-pass filter to reject noise.

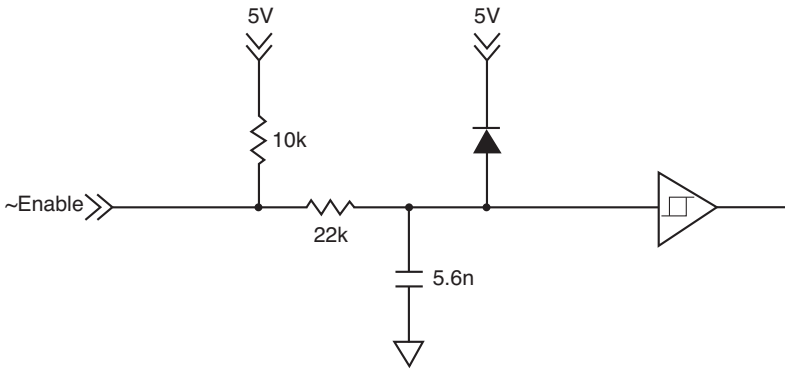


Figure 3-4: Signal Interfacing ~Enable

3.8.2 FaultOut

FaultOut is asserted high when a fault occurs. Fault conditions can be programmed by the external controller to control the FaultOut output.

An Atlas FaultOut output circuit is shown in diagram Figure 3-5. This circuit can continuously sink 50mA when pulled low. It has a 150kohm pull-up resistor to 5V. Its voltage range is 0 to 24V.

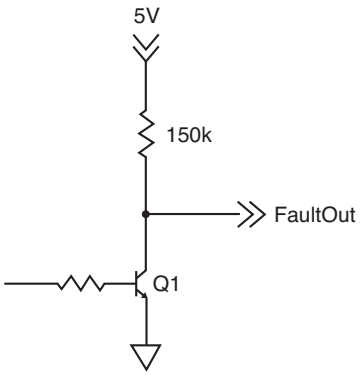


Figure 3-5: Signal Interfacing FaultOut

3.9 Connection Overview

3.9.1 Brushless DC Motors

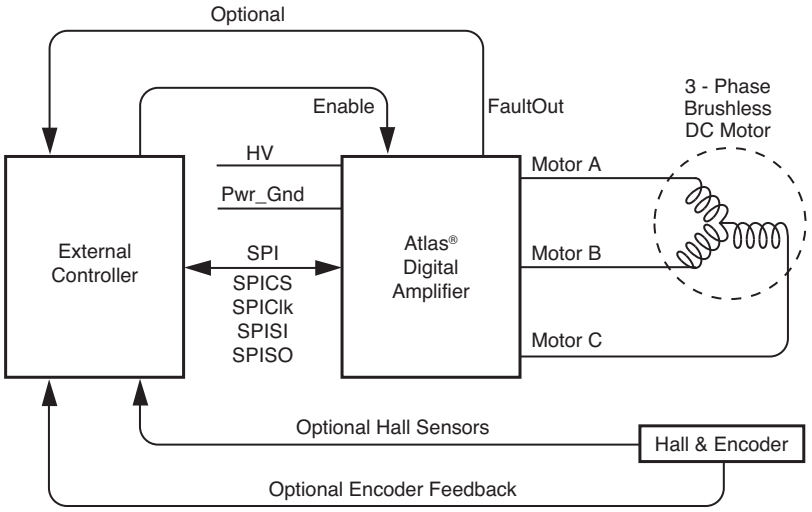


Figure 3-6: Brushless DC Connections

The following table summarizes the recommended connections when connecting Atlas amplifiers to brushless DC motors

Type	Required Connections	Optional Connections
Power	HV (2 pins), Pwr_Gnd (2 pins)	
Communication	~SPICS, SPISO, SPISI, SPIClk, GND	
Motor	Motor A, (2 pins) Motor B (2 pins), Motor C (2 pins)	
Miscellaneous	~Enable	FaultOut

If Atlas is used as part of a higher level position controller, as shown in the Figure 3-6, the Brushless DC motor provides feedback signals to the external controller. Commonly, both Hall sensor signals and a position encoder are used, but only one or the other is needed in a minimal configuration. In this configuration the external controller generally consists of a PMD Magellan Motion Processor or a programmable microprocessor or DSP-type device.

Alternatively, Atlas can be operated by an external controller as a standalone device, driving the motor at commanded voltage or torque levels and not part of a higher-level servo controller. In this configuration, the external controller can be either a microprocessor-type device, or a logic device such as an FPGA (field programmable gate array).

Atlas functions as a power block providing amplification, current control, and safety management of the amplifier and motor. Atlas does not directly accept Hall signals or encoder signals, so to operate with a brushless DC motor the motor's current phase angle must be provided by the external controller through the SPI interface.

The Atlas does not support direct Hall signal inputs. To operate the Atlas with a Brushless DC motor, continuous motor phase angle is provided by the external controller, via either Hall inputs or an encoder.

3.9.2 DC Brush Motors

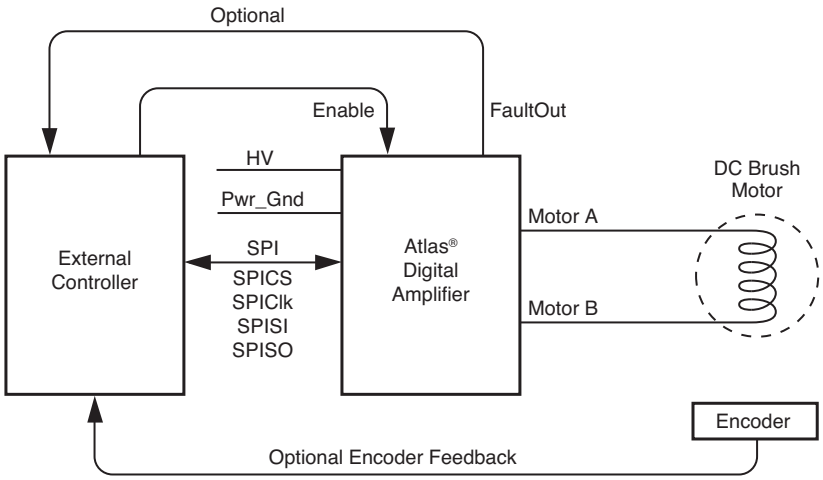


Figure 3-7: DC Brush Connections

The following table summarizes the recommended connections when connecting Atlas amplifiers to DC Brush motors.

Type	Required Connections	Optional Connections
Power	HV (2 pins), Pwr_Gnd (2 pins)	
Communication	~SPICS, SPISO, SPISI, SPIClk, GND	
Motor	Motor A (2 pins), Motor B (2 pins)	
Miscellaneous	~Enable	FaultOut

If Atlas is used as part of a higher level servo controller, as shown in Figure 3-7, an encoder provides position or velocity feedback signals to the external controller. In this configuration the external controller generally consists of a PMD Magellan Motion Processor or a programmable microprocessor or DSP-type device.

Alternatively, Atlas can be operated by an external controller as a standalone device, driving the motor at commanded voltage or torque levels. In this configuration the external controller can be either a microprocessor-type device, or a logic device such as an FPGA (field programmable gate array).

3.9.3 Step Motors in Pulse & Direction Signal Mode

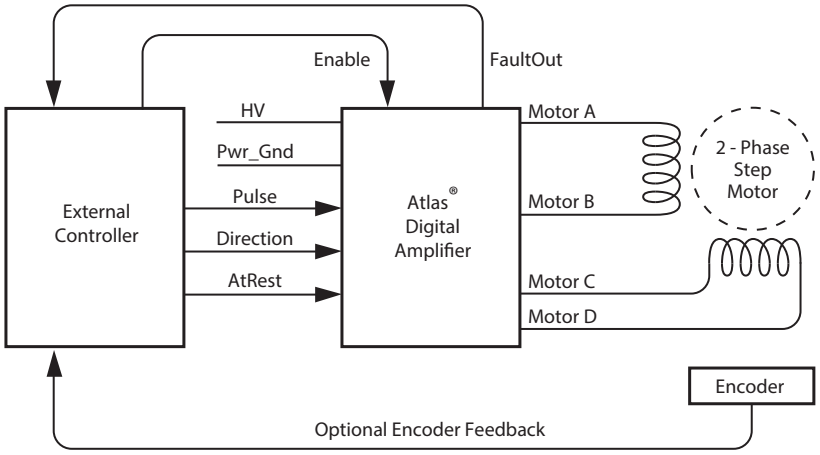


Figure 3-8: Step Motor Pulse and Direction Mode Connections

The following table summarizes the recommended connections when connecting Atlas amplifiers to two-phase step motors when using the pulse & direction signal mode. In this mode the external controller provides position commands to Atlas via pulse and direction signals.

Type	Required Connections	Optional Connections
Power	HV (2 pins), Pwr_Gnd (2 pins)	
Communication	Pulse, Direction, GND	AtRest
Motor, Phase A^+:	Motor A (2 pins)	
Motor, Phase A^-	Motor B (2 pins)	
Motor, Phase B^+:	Motor C (2 pins)	
Motor, Phase B^-:	Motor D (2 pins)	
Miscellaneous	~Enable	FaultOut

These connections apply to bipolar motors. If connecting to unipolar motors do not connect the center tap.

In this configuration the external controller generally consists of an off-the-shelf motion control card or module, a programmable microprocessor or DSP-type device, or a FPGA (field programmable gate array). The external controller provides a continuous stream of pulse and direction commands, along with (optionally) an *AtRest* signal to control the torque.

To initially set up and store its application-specific configuration parameters, Atlas is programmed using the SPI interface and then commanded to convert to pulse & direction signal mode.

3.9.4 Step Motor Using SPI Communications

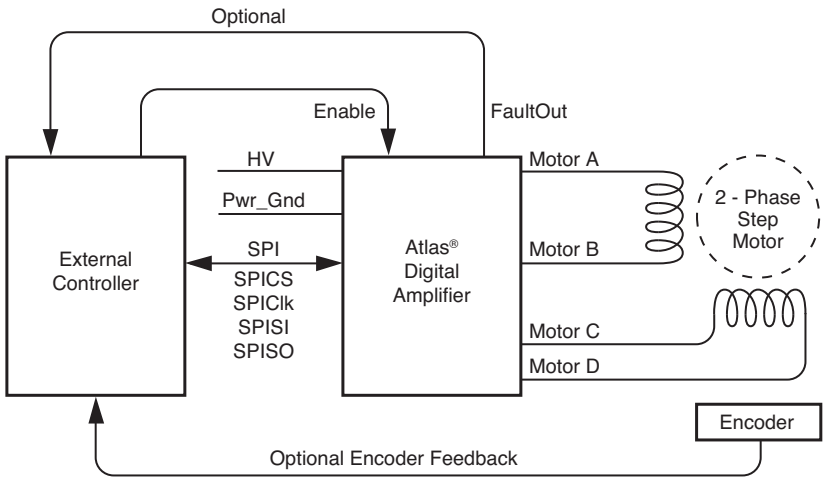


Figure 3-9: Step Motor SPI Communication Connections

The following table summarizes the recommended connections when connecting Atlas amplifiers to two-phase step motors when using the SPI communications channel. In this mode the external controller provides position commands to Atlas via the SPI interface.

Type	Required Signal Connections	Optional Signal Connections
Power	HV (2 pins), Pwr_Gnd (2 pins)	
Communication	~SPICS, SPISO, SPISI, SPIClk, GND	
Motor, Phase A^+:	Motor A (2 pins)	
Motor, Phase A^-	Motor B (2 pins)	
Motor, Phase B^+:	Motor C (2 pins)	
Motor, Phase B^-:	Motor D (2 pins)	
Miscellaneous	~Enable	FaultOut

These connections apply to bipolar motors. If connecting to unipolar motors do not connect the center tap.

In this configuration the external controller generally consists of a PMD Magellan Motion Processor, a programmable microprocessor or DSP-type device, or a FPGA (field programmable gate array). The external controller provides a continuous stream of position commands or individual phase torque output commands to control the motor position.

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4. Operation

4

In This Chapter

- Functional Overview
- Internal Block Diagram
- Commutation
- Current Loop
- Power Stage
- Status Registers
- Safety Processing Functions
- Step Motor Control
- User Memory Space & Buffers
- Trace Capture
- Power-up & Non-Volatile Initialization Storage
- SPI Communications Overview

4.1 Functional Overview

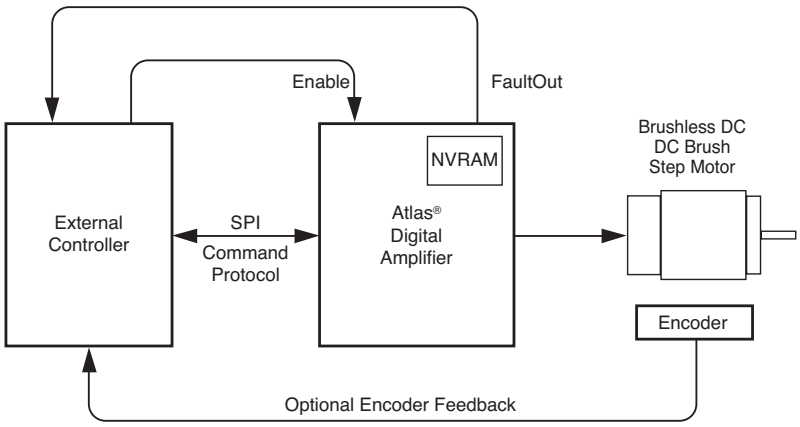


Figure 4-1: High Level System Diagram

Atlas Digital Amplifiers are single-axis devices for torque or voltage-mode control of three-phase brushless DC motors, DC Brush motors, or two-phase step motors. They accept a stream of desired torque or voltage values from an external controller and perform all current loop processing and switching bridge control to continuously drive the motor coils to the specified, commanded values.

In addition to providing a stream of torque or voltage commands, the external controller is used to set up operational parameters needed by Atlas such as control gains, safety-related parameters, and other information. These parameters may be provided to Atlas at each power up, or stored non-volatilely on Atlas so that they no longer need to be loaded at each power-up. See Section 4.11, "Power-up & Non-Volatile Initialization Storage" for more information.

Communication to/from Atlas occurs via an SPI interface and associated protocol that uses packet-oriented commands to specify various Atlas parameters, and, if desired, request status information from Atlas. This protocol has been designed for maximum speed and flexibility so that torque or voltage commands can be continuously sent to Atlas even while the external controller queries Atlas for various information. Please refer to the *Atlas Digital Amplifier Complete Technical Reference* for information on the SPI interface.

At power-up or reset, Atlas checks for the presence of stored configuration information in its non-volatile memory. If no such configuration information is found, default values are used.

When Atlas is used in a higher level system such as a servo-based velocity or position controller, torque commands are typically sent to Atlas continuously, at the motion controller's sample servo rate. For most systems this rate is in the 1,000 to 10,000 samples per second range. However Atlas may also be used with direct voltage or torque control applications that utilize Atlas to specify a desired output value just once after power-up, or only occasionally as required by the application.

To disable Atlas operations it may be powered down, the ***Enable*** signal may be de-asserted, or various commands that result in Atlas operations being suspended may be sent by the external controller to Atlas through the SPI interface. In addition, there are several conditions where Atlas automatically shuts down for safety-related reasons. These may include short circuit detection, under and over voltage protection, I^2t current limiting, and amplifier over temperature detection. See Section 4.7, "Safety Processing Functions" for more information on emergency stop and related functions.

4.2 Internal Block Diagram

Figure 4-2: Internal Block Diagram

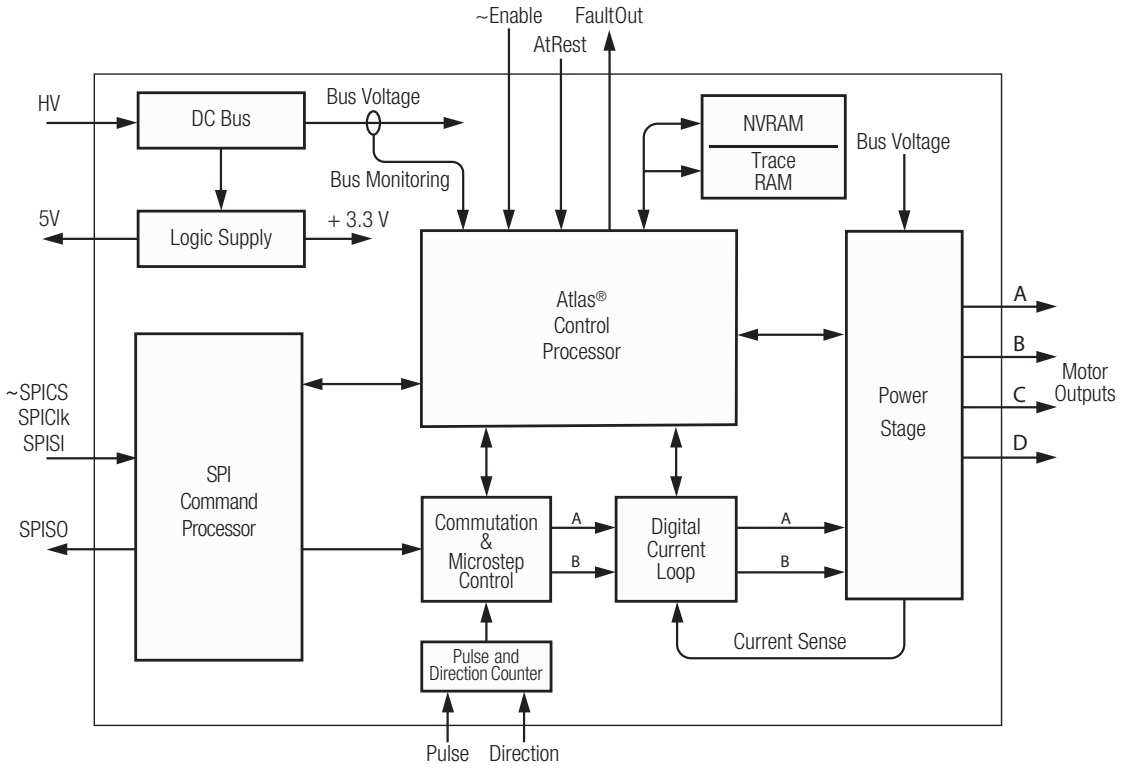


Figure 4-2 shows the internal block diagram of Atlas. Here are summary descriptions of the major modules and functional areas:

Commutation—this module utilizes internally generated information, or information provided by the external controller, to split up the desired overall torque command into individual phase commands to drive Brushless DC and step motors.

Current Loop—this module inputs the desired current for each of the two motor coils and uses the measured current feedback from each motor coil to develop PWM (pulse width modulation) output command values for the power stage. The current loop module may be disabled, in which case Atlas will drive the motor in voltage mode. See Section 4.4, "Current Loop" for more information on the current loop module.

Power Stage—this module receives desired voltages for each motor coil and manages the Atlas unit's high performance MOSFET-based switching bridge to precisely drive the coils of the motor. See Section 4.5, "Power Stage" for a detailed description of this module.

Status Registers—this module holds various status registers including the Event Status Register, the Drive Status register, the Signal Sense register, and the Drive Fault Status Register.

Safety Processing—this module manages Atlas unit safety-related functions including the internal temperature sensor, bus voltage error, the ***Enable*** input signal, current foldback, the ***FaultOut*** output signal, event action processing, and more.

Step Motor Processing—this module implements step motor-specific features including microstep signal generation, holding current management, and ***Pulse***, ***Direction***, and ***AtRest*** signal processing.

Memory Buffers—this module provides user-accessible memory for trace and setup parameter configuration storage.

Trace—this module provides a facility for continuously storing up to four simultaneous Atlas variables in the memory buffers.

Power-up & Non-Volatile Initialization Storage—this module manages the power-up sequence and provides the ability to store selected parameters into the Atlas unit's non-volatile memory.

SPI Command Processor—This module manages all communications to/from the external controller.

4.3 Commutation

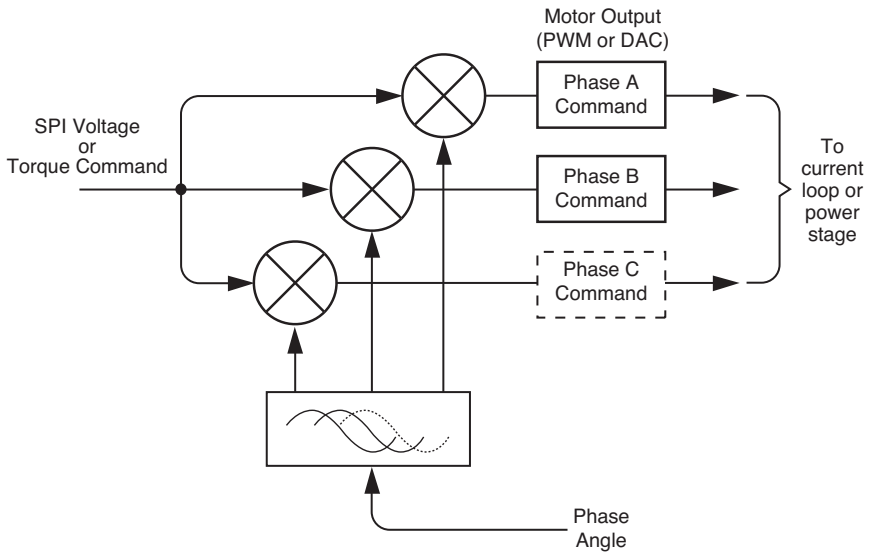


Figure 4-3: Commutation Control Sequence

Brushless DC motors have three phases (generally referred to as A, B, and C) separated from each other by 120 electrical degrees. The process of splitting up the overall torque command into constituent phase commands is called commutation. Figure 4-3 provides an overview of the control sequence when a brushless DC motor is controlled by Atlas.

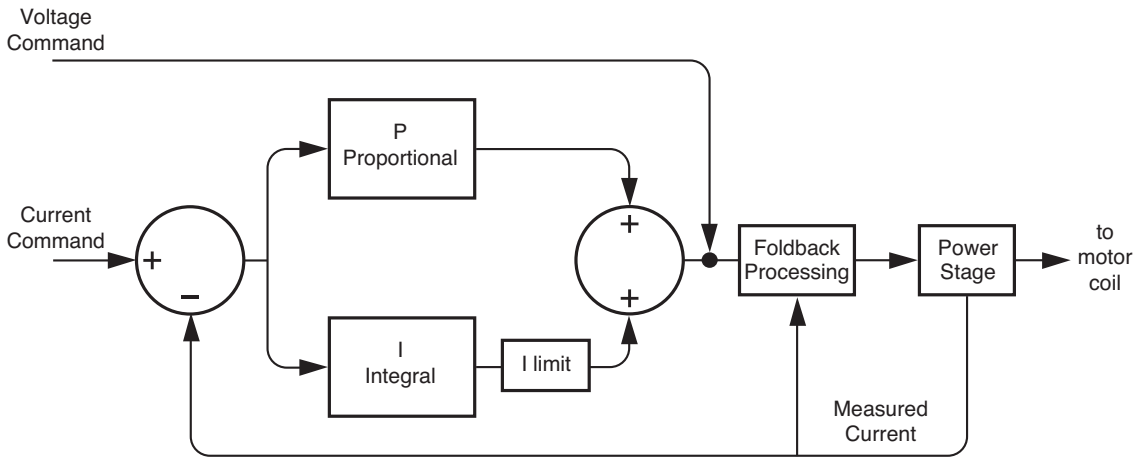
The first step is that the external controller specifies the desired motor voltage or torque command to the Atlas. This command is then commutated into constituent phase-specific values. This process applies to step motors as well as Brushless DC motors, however for step motors the process is called microstepping. See Section 4.8, "Step Motor Control" for a detailed discussion of step motor control with Atlas amplifiers. DC Brush motors are single phase devices, and do not require commutation.

Once commutated, the individual commands for the A, B, and C phases are output either directly to the power stage or to the current loop module (depending on whether current control has been requested). If output to the current loop module, additional calculations are performed using the measured current through each winding to determine a final phase command. See Section 4.4, "Current Loop" for details.

Atlas does not directly accept commutation inputs such as Hall sensors, so phase angle information must be provided by the external controller via the SPI interface. When used with the Magellan Motion Processor all such phase information is provided automatically. When used with other external controllers, for detailed information on how to provide this phase angle information, as well as other details of Atlas commutation operations, refer to the *Atlas Digital Amplifier Complete Technical Reference*.

4.4 Current Loop

Figure 4-4: Current Loop Control Flow



Digital current control is a technique used with DC brush, brushless DC, and step motors for precisely controlling the current through each winding of the motor. By controlling the current, response times are improved and motor efficiency is increased.

Figure 4-4 provides an overview of Atlas unit's current controller. For single-phase motors such as DC brush, one current loop per axis is used. For brushless DC motors, two current loops are used and the third phase command is derived from the other two phases. When driving step motors, two current loops are used, one for the phase A coil, and one for the phase B coil.

There are three overall methods of current control provided by Atlas, however not all methods are used with all motor types. The first method is individual phase control. See Section 4.4.1, "Individual Phase Control" for a description. See Section 4.4.2, "Field Oriented Control" for a description of the second method, FOC (Field Oriented Control).

See Section 4.4.3, "Third Leg Floating Control" for a description of the third approach, called 'third leg floating.' The table below summarizes which current control modes are available with the three motor types supported by Atlas, along with the default configuration for that motor type.

Current Control Method	Brushless DC	DC Brush	Step Motor
Individual Phase Control	✓	✓ (default)	✓
Field Oriented Control	✓ (default)		✓ (default)
Third Leg Floating	✓		

The large majority of applications will use FOC to drive Brushless DC or step motors. FOC usually provides the highest top speeds and more energy efficient operation of the motor compared to individual phase control. Third leg floating is an option that should generally only be considered for Hall-commutated motors. In that configuration, third leg floating can sometimes provide a higher top speed than FOC. Finally, individual phase control is always used with DC Brush motors, and may, under certain specialized conditions, provide improved performance for Brushless DC motors over FOC.

If during normal operation the current loop is disabled, then the output from the commutation module will pass directly to the power stage module, with no current control being performed. The most common use of this is to run the amplifier in voltage mode, which may be useful under some conditions for calibration or testing.

4.4.1 Individual Phase Control

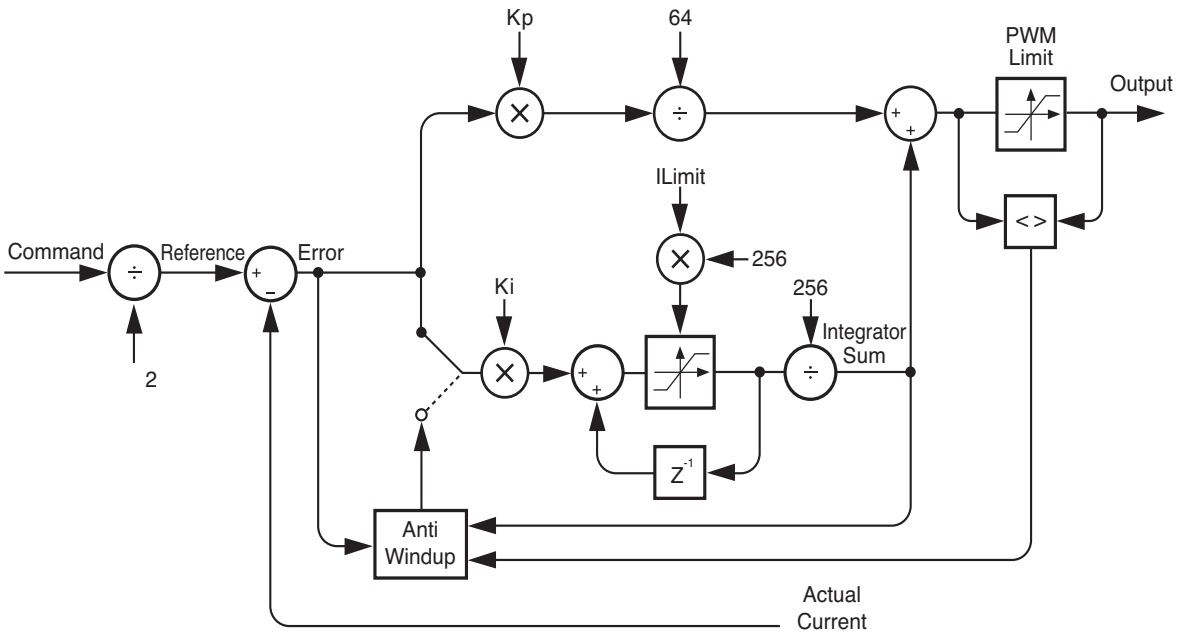


Figure 4-5: Individual Phase Control Calculation Flow

When individual phase control mode is selected Atlas utilizes the commanded current for each motor winding provided by the commutation module, along with the actual measured current provided by circuitry within the power stage, to perform current loop calculations.

As can be seen in Figure 4-5, the desired current and measured current are subtracted to develop a current error, which is passed through a PI (proportional, integral) filter to generate an output voltage command for each motor coil. The output command for each coil is then passed to the power stage module to generate precise PWM (pulse width modulation) output signals, representing the applied voltage, that control the power stage's switching bridge.

Three parameters are set by the user to control the current loop; *Kp*, *Ki*, and *Ilimit*. Two of these are gain factors for the PI controller, and the other is a limit for the integral contribution.

It is the responsibility of the user to determine control parameters that are suitable for use in a given application.

4.4.1.1 Reading Current Loop Values

To facilitate tuning there are a number of current loop values that can be read back as well as traced.

The variables within the current loop that can be read or traced when the control loop mode is set to individual phase control are summarized in the following table. Refer to Figure 4-5 when viewing this table.

Variable Name	Function
Phase A Reference, Phase B Reference	*Brushless DC & microstepping motor:* These registers hold the commanded (reference) currents for the phase A and phase B coils. *DC Brush motor:* Phase A Current holds the commanded (reference) current for the motor.
Phase A Current, Phase B Current, Phase C Current	*Brushless DC:* These registers hold the measured actual currents for the phase A, phase B, and phase C coils. *Step motor:* These registers hold the measured currents for the phase A, and phase B coils. *DC Brush motor:* Phase A Current holds the measured current for the motor.
Phase A Error, Phase B Error	*Brushless DC & microstepping motor:* These registers hold the difference between the current loop reference and the measured current value (Phase A Current, Phase B Current). *DC Brush motor:* The Phase A Error register holds the difference between the current reference and the measured current value (Phase A Current).
Phase A Integrator Sum, Phase B Integrator Sum	*Brushless DC & microstepping motor:* These registers hold the sum of the integrator for the phase A and B current loops. *DC Brush motor:* Phase A Integrator Sum holds the sum of the integrator for the current loop
Phase A Output, Phase B Output	*Brushless DC & microstepping motor:* These registers hold the output command for the phase A and B current loop. *DC Brush motor:* Phase A Output holds the output command for the current loop

4.4.1.2 Individual Phase Control with Step Motors

The Atlas unit's individual phase control mode is designed to work with both 3-phase brushless DC motors and 2-phase step motors. When operating step motors in this mode (see Section 4.8, "Step Motor Control" for more information on operations with step motors), the basic method is identical. The same three current loop parameters described in Section 4.4.1, "Individual Phase Control" are set, and the readable parameters are also the same.

4.4.1.3 Individual Phase Control in Voltage Mode

If Atlas is operated in individual phase control mode with the current loop disabled, then after commutation (Brushless DC motors) or microstep signal generation (step motors) the phase-specific commands are output directly to the power stage with no current loop performed.

For example, if the incoming torque command provided by the external controller is 25% full scale, then for an Atlas that is operating with a bus voltage of 24V, the average voltage presented at the motor coil will be 25% of 24V or 6V. For single phase motors such as DC Brush, the PWM generator directly outputs this external controller-commanded value to the power stage. For multi-phase motors such as brushless DC or step motor, the PWM generator outputs this commanded value after commutation (brushless DC motors) or microstep signal generation (step motors) to the power stage.

See Section 4.5, "Power Stage" for more information on power stage operations.

4.4.2 Field Oriented Control

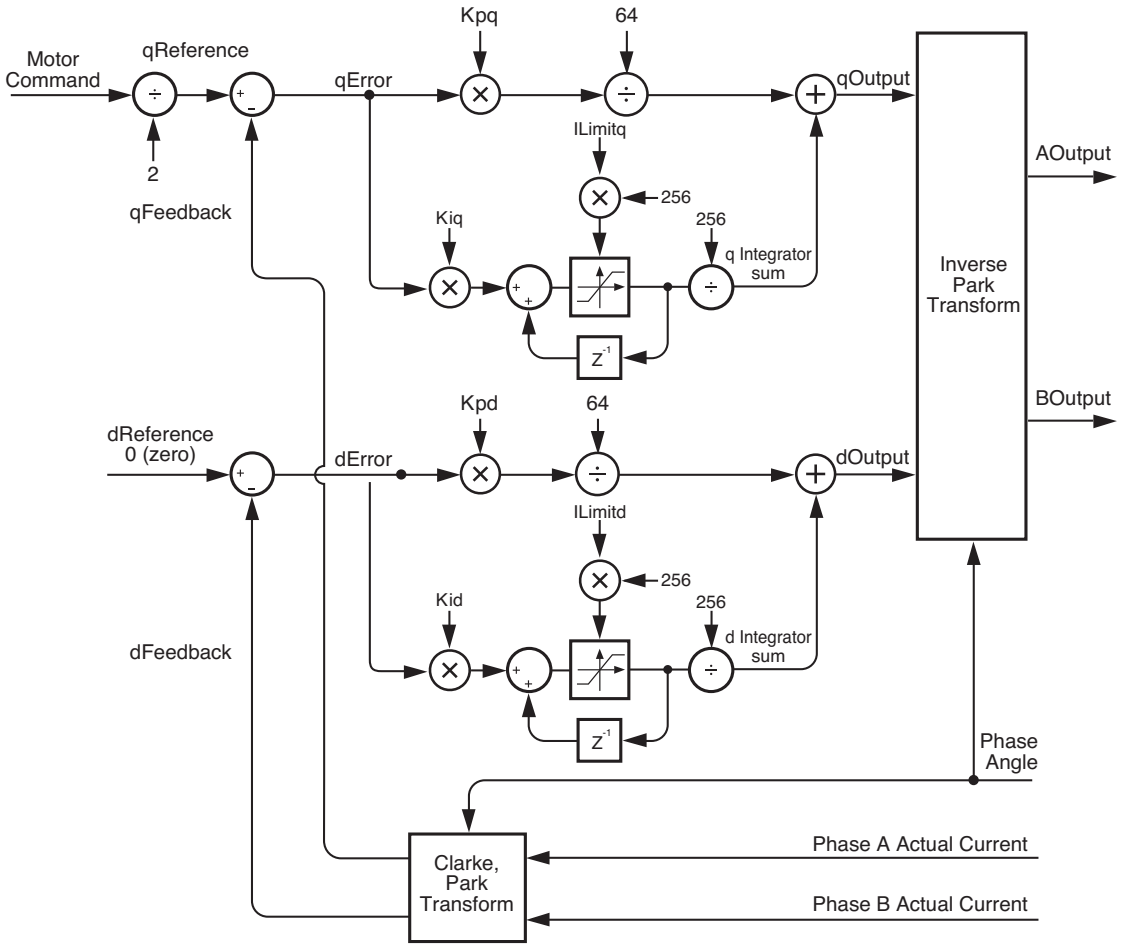


Figure 4-6: Field Oriented Control Calculation Flow

Figure 4-6 provides an overview of the calculation flow when field oriented control (FOC) is selected. Instead of separating phases as individual phase control mode does, FOC combines them and "re-references" them to what are known as d (direct torque) and q (quadrature torque) reference frames.

For each control loop (d and q) three parameters are set by the user, Kp, Ki, and I limit. Two of these are gain factors for the PI (proportional, integral) controller that comprises the heart of the FOC controller, and the other is a limit for the integral contribution.

It is the responsibility of the user to determine control parameters that are suitable for use in a given application.

4.4.2.1 Reading FOC Loop Values

To facilitate tuning there are a number of FOC loop values that can be read back as well as traced.

Refer to Figure 4-6 for an overview of the FOC loop. The variables within the FOC loop that can be read or traced are summarized as follows:

Variable Name	Function
q Reference, d Reference	Are the commanded values input into the q and d loops. Note that d is always set to 0 (zero).
q Feedback, d Feedback	Are the measured values for the q (quadrature) and d (direct) force after re-referencing from the actual measured current in the phase A, phase B coils.
q Error, d Error	Are the differences, for the q loop and the d loop, between the loop reference and the loop measured value.
q Integrator Sum, d Integrator Sum	Are the integrator sums for the d and q loops.
q Output, d Output	Are the output commands of the q and the d loops.
FOC α Output, FOC β Output	Are the FOC outputs in the α, β reference frame.
Phase A Actual Current, Phase B Actual Current	Are the measured currents for the phase A and phase B coils.

4.4.2.2 FOC with Step Motors

The Atlas unit's field oriented control algorithm is designed to work with both 3-phase brushless DC motors and 2-phase step motors. When operating step motors in this mode (see Section 4.8, "Step Motor Control" for more information on operations with step motors), the basic method is identical. The same three FOC parameters described in Section 4.4.2, "Field Oriented Control" are set, and the readable parameters are also the same.

4.4.2.3 FOC in Voltage Mode

If Atlas is operated in FOC mode with the current loop disabled, then after commutation (Brushless DC motors) or microstep signal generation (step motors) the phase-specific commands are output directly to the power stage with no current loop performed.

However unlike the independent phase control mode, a space vector modulation scheme is used to generate the PWM signals and control the switching bridge. Space vector modulation is recommended for most applications because it provides a larger effective range of voltage drive capacity.

See Section 4.5, "Power Stage" for more information on power stage operations.

4.4.3 Third Leg Floating Control

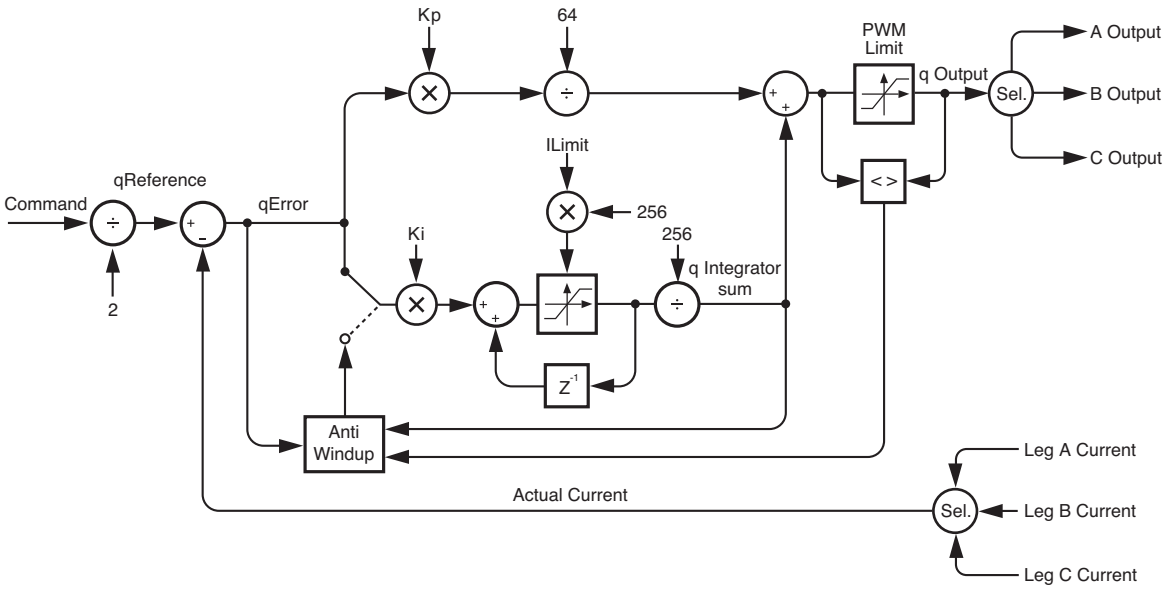


Figure 4-7: Third Leg Floating Control

Figure 4-7 provides an overview of the calculation flow when third leg floating control mode is selected. Compared to individual phase control or FOC, third leg floating uses a different method in that only two of three legs are driven at any instant with the third, non-driven, leg floating. The actual driven and non-driven legs continuously change based on the phase, as does the leg current used as input to the current loop. In this way, as the motor rotates, each motor leg will go through a sequence of being driven for two cycles and then left floating for one.

Other than the method by which the motor phases are driven and the leg current is sensed, third leg floating is similar to FOC, however with only the q loop calculated. For the q current loop three parameters are set by the user, Kp, Ki, and Ilimit. Two of these are gain factors for the PI (proportional, integral) controller that comprises the heart of the third leg floating controller, and the other is a limit for the integral contribution.

It is the responsibility of the user to determine control parameters that are suitable for use in a given application.

The third leg floating control mode is applicable to Brushless DC motors only.

4.4.3.1 Reading Third Leg Floating Loop Values

To facilitate tuning there are a number of third leg floating loop values that can be read back as well as traced.

Refer to the diagram in Section 4.4.3, "Third Leg Floating Control" for an overview of the control loop. The variables that can be read or traced are summarized as follows:

Variable Name	Function
q Reference	Is the commanded value input into the q loop.
q Feedback	Is the measured value of the q component of the current

Variable Name	Function
q Error	Is the difference between the measured q component of the current and the commanded q component.
q Integrator sum	Is the integrator sum for the q loop.
q Output	Is the output command of the q loop
q Actual Current	Is the measured current for the q current

4.4.3.2 Third Leg Floating in Voltage Mode

If Atlas is operated in third leg floating mode with the current loop disabled then the external controller-provided torque command is used to specify PWM duty cycle (voltage) to two out of the three motor output terminals, one positive and one negative. The third terminal is put into a high impedance (floating) state. Which terminal is positive, negative, or floating depends on the controller-provided phase angle.

4.5 Power Stage

Atlas contains a high performance MOSFET-based power stage that utilizes one or more switching bridges to drive the motor coils. A slightly different configuration is used for each motor type:

- DC Brush motors are driven with an H-bridge consisting of 4 FETs.
- Brushless DC motors are driven with a 3-phase bridge consisting of 6 FETs
- Step motors are driven with two H-bridges, one for each phase, for a total of 8 FETs.

The use of 3-phase and H-bridge topologies provides full 4-quadrant operation for all motor types. In addition, Atlas uses an advanced PWM switching scheme that minimizes the ripple current on the motor windings while maximizing the current loop performance. The fundamental frequency of the ripple current is twice the PWM frequency, and well out of the audible range in all cases.

The PWM frequency is selectable between 20 kHz, 40kHz, and 80kHz to cover a broad range of motor inductances.

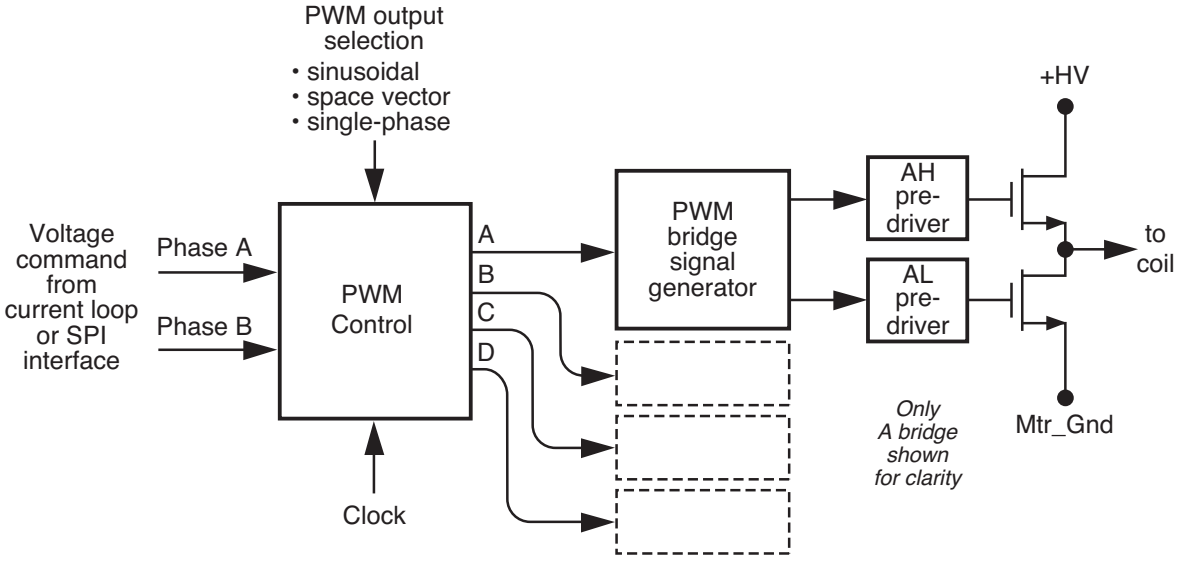


Figure 4-8: Power Stage Control Flow

In addition to the output bridge function, Atlas provides a current measurement function for use by the current loop module as well as by the safety processing module. Two channels of phase current feedback are provided for brushless DC and step motor current loops. For DC Brush motors feedback for one phase is provided.

Three selectable control methods are provided; independent phase, field oriented control, and third leg floating. The choice of control method affects the power stage in the selection of the PWM generation technique. The table below shows this.

Control Mode	PWM Output Method
Independent Phase	sinusoidal
Field Oriented Control	space vector modulation
Third Leg Floating	standard single-phase

4.5.1 PWM Output Limiting

In some applications it may be desirable to limit the maximum allowed output of the power stage PWM generator. For example if the bus voltage is 36 volts, and the desired voltage limit for a particular motor is 18 volts, a PWM limit of 50% is programmed.

Depending on the Atlas unit bus voltage and the effective inductance of the system being controlled, under some circumstances lowering the maximum PWM duty cycle may not fully limit the effective voltage experienced by the device. If this is the case for your system, you may consider increasing the Atlas unit PWM frequency, adding an inductor to the motor circuit, or consulting a PMD representative for more information.

The programmed drive limit value affects the PWM duty cycle only. It does not limit the effective current that is delivered to the motor. To explicitly limit the current, the current foldback mechanism can be used. See Section 4.7.9, "Current Foldback" for more information.

4.5.2 Disabling the Power Stage

During normal operation the Atlas unit's primary function is to drive the motor at the torque or voltage requested by the external controller. However there are a number of circumstances where it may be desirable to disable the power stage. In particular, the power stage may be disabled if certain safety-related conditions occur, or for system calibration. See Section 4.7, "Safety Processing Functions" for more information on Atlas safety processing.

If the power stage module is disabled, all external controller-provided voltage or torque commands are ignored, and all bridge FETs are turned off. This has the effect of "free-wheeling" the motor, which means the motor may stop, coast, or even accelerate (if a constant external force exists such as a gravitational load) depending on the load, inertia, and configuration of the axis mechanics.

A previously disabled power stage module may be re-enabled. At the time that the re-enable operation is requested, the power stage module will immediately begin normal operations. Care should therefore be taken to re- enable the power stage when the motor axis is in a stable condition such that no abrupt motion occurs.

If Atlas is in a condition where the current loop module also needs to be re-enabled, both the power stage and the current loop module should be enabled at the same time. This is normally the case when recovering from all safety processing conditions. See Section 4.7, "Safety Processing Functions" for more information.

It is the responsibility of the user to manage the operation of the power stage so that appropriate safety conditions are maintained at all times.

4.6 Status Registers

In addition to various numerical registers that may be queried by the external controller, there are four bit-oriented status registers.

These status registers conveniently combine a number of separate bit-oriented fields into a single register. These registers are Event Status, Drive Status, Signal Status, and SPI Status Register. The external controller may directly query these four registers, or the contents of these registers may be utilized by other functional portions of Atlas, such as ***FaultOut*** signal processing. See Section 4.7.8, "FaultOut Signal" for more information on ***FaultOut*** processing.

Refer to the *Atlas Digital Amplifier Complete Technical Reference* for a description of these status registers.

4.7 Safety Processing Functions

Atlas provides a number of amplifier control features that automatically detect and manage safety-related conditions. In addition, Atlas can signal when various conditions, safety or otherwise, occur.

The subsequent sections describe these features.

4.7.1 Overcurrent Fault

Atlas supports automatic detection of excessive current output. This fault occurs when the motor, the wiring leading from Atlas, or Atlas unit's power stage becomes short circuited.

An overcurrent fault will cause the current loop and power stage modules to be disabled, thereby halting further motor output. To recover from this condition the user should determine the nature of the fault. It is generally desirable to power down Atlas to check connections or otherwise correct the Atlas-attached hardware so that the problem does not occur again.

If the overcurrent condition has been resolved, when restart is attempted Atlas will resume normal operations. If the overcurrent condition has not been resolved, the overcurrent condition will immediately occur again.

Over current faults are serious conditions and warrant the utmost precaution before re-enabling amplifier operation. It is the responsibility of the user to determine the cause and corrective action of any electrical fault.

4.7.2 Overtemperature Fault

Atlas provides the capability to continually monitor and detect excessive internal temperature conditions. Such a condition may occur if excessive current is requested, if heat sinking of the Atlas unit is inadequate, or if some other problem results in elevated drive temperatures.

To detect this condition a programmable temperature threshold is continuously compared to an internal temperature sensor. If the value read from the internal sensor exceeds the programmed threshold, an overtemperature fault occurs. In addition, a settable overtemperature hysteresis allows the user to ensure that the Atlas temperature drops by a specified number of degrees before allowing drive restart.

The maximum allowed setting for the temperature threshold is 75.0° C, which is also the default value. The maximum allowed value of the hysteresis parameter is 50° C, and the default value is 5° C.

An over temperature fault will cause the current loop and power stage modules to be disabled, thereby halting further motor output. To recover from this condition the user should determine the nature of the fault. It is generally desirable to power down Atlas to correct the condition.

If the overtemperature condition has been resolved, when restart is attempted Atlas will resume normal operations. If the overtemperature condition has not been resolved, the condition will immediately occur again.

Overtemperature faults indicate that the internal safe limit of the drive temperature range has been exceeded. This potentially serious condition can result from incorrect motor connections, excessive power demands placed on the Atlas amplifier, or inadequate heat sinking . It is the responsibility of the user to operate Atlas within safe limits.

4.7.3 Overvoltage Fault

Atlas provides the capability to continually monitor and detect excessive voltages on the incoming voltage supply. Such a condition may occur if there is a fault in the system power supply, if a large back EMF (electro motive force) is generated during motor deceleration, or if some other problem results in an elevated bus voltage.

To detect this condition a programmable bus voltage threshold is continuously compared to the bus voltage sensor. If the value read from the internal sensor exceeds the programmed threshold, an overvoltage fault occurs.

The maximum allowed setting for the overvoltage threshold is 60.0 volts, which is also the default value. The minimum allowed threshold is 10.0 volts.

An overvoltage fault will cause the current loop and power stage modules to be disabled, thereby halting further motor output. To recover from this condition the user should determine the nature of the fault. In most cases it is desirable to power down Atlas to correct the condition.

If the overvoltage condition has been resolved, when restart is attempted Atlas will resume normal operations. If the overvoltage condition has not been resolved, the condition will immediately occur again.

Overvoltage faults indicate that a serious safety condition has occurred. It is the responsibility of the user to operate Atlas within safe limits.

4.7.4 Undervoltage Fault

Atlas also provides the capability to sense undervoltage conditions. This value is compared to the value read from the drive DC bus, and if the value read is less than the programmed threshold, an undervoltage fault occurs. The minimum allowed value for this threshold is 10.0 volts, which is also the default value. The maximum allowed value is 56.0 volts.

All other aspects of this feature are the same as for overvoltage sense. Just as for overvoltage conditions, it is the user's responsibility to determine the seriousness of, and appropriate response to, an undervoltage condition.

4.7.5 Watchdog Timeout

Atlas provides a programmable watchdog timer that can detect an unexpected lack of activity from the external controller. Typically, such a condition is due to an SPI communication problem or an external controller malfunction. Particularly when the external controller is used to provide higher level velocity or position control, a watchdog timeout may therefore represent a very serious condition.

To effect the watchdog function Atlas monitors the amount of time between successive valid SPI torque or voltage commands from the external controller. If the amount of time between commands exceeds the programmed watchdog timer, the watchdog fault is triggered.

A watchdog timeout fault will cause the current loop and power stage modules to be disabled, thereby halting further motor output. To recover from this condition the user should determine the nature of the fault. In most cases it is desirable to power down Atlas to correct the condition.

Watchdog timeout faults indicate that a serious safety condition has occurred. It is the responsibility of the user to operate Atlas within safe limits.

4.7.6 Drive Enable

Atlas supports an ***Enable*** input signal that must be active for proper amplifier operation. This signal is useful for allowing external hardware to automatically shut Atlas down. The signal has an active low interpretation.

If the Enable signal becomes inactive (goes high) the current loop and power stage modules are disabled, thereby halting further motor output. To recover from this condition the user should determine the nature of the fault. It may be desirable to power down Atlas to correct the condition.

4.7.7 Drive Fault Status Register

To simplify recovery from drive-related faults Atlas provides a Drive Fault Status register. Refer to the *Atlas Digital Amplifier Complete Technical Reference* for more information on this register.

4.7.8 FaultOut Signal

The Atlas unit's ***FaultOut*** signal is used to indicate an occurrence of one or more drive faults. This signal is active high, meaning it is high when a fault has occurred, and it is low when a fault has not occurred.

The ***FaultOut*** signal is programmable, so that the user may determine what fault states result in the ***FaultOut*** signal becoming active. In particular, any bit condition of the Drive Fault Status register may be used to trigger activation of the ***FaultOut*** signal.

For complete information on ***FaultOut*** signal programming and the Drive Fault Status register, refer to the *Atlas Digital Amplifier Complete Technical Reference.*

4.7.9 Current Foldback

Current foldback, also known as I^2t foldback, is a general purpose tool to protect the drive output stage or the motor from excessive current.

I^2t current foldback works by integrating, over time, the difference of the square of the actual motor current and the square of a user-settable continuous current limit. When the integrated value reaches a user-settable energy limit, Atlas

goes into current foldback. When in this condition Atlas will attempt to clamp the maximum current to the continuous current limit value. Note that the Atlas unit's ability to do so depends on a properly functioning current loop.

Atlas will stay in foldback until the integrator returns to zero. This is shown in Figure 4-9.

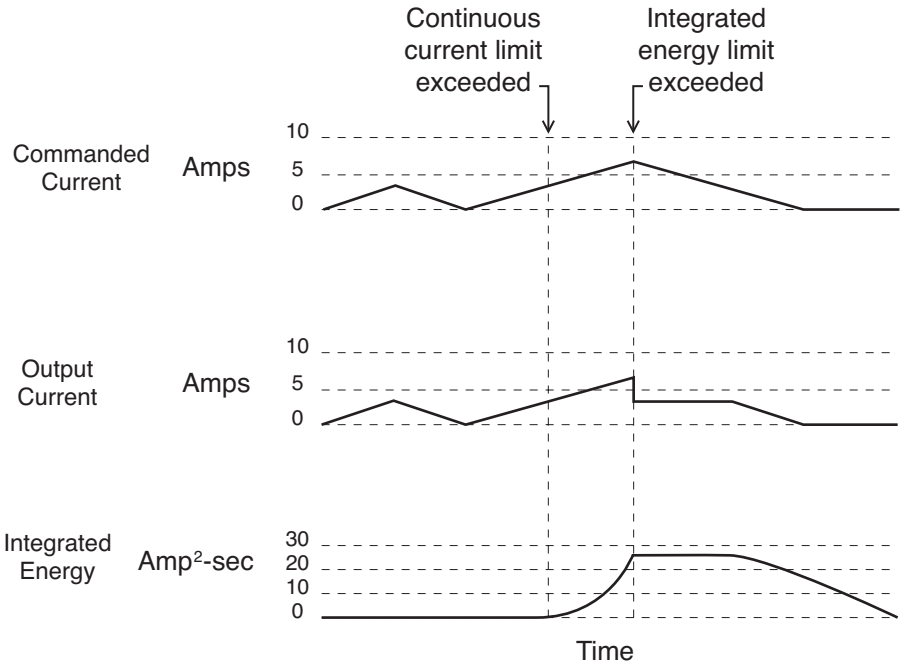


Figure 4-9: Current Foldback Processing Example

Each Atlas amplifier motor type has particular default and maximum allowed values for both the continuous current limit and energy limit. These values are designed to protect the Atlas from excessive heat generation. The table below shows these values.

Motor Type	Continuous Current Limit Default	Continuous Current Limit Maximum	Energy Limit Default	Energy Limit Maximum
Brushless DC	9.0 Amps	10.0 Amps	139 Amp^2Sec	139 Amp^2Sec
DC Brush	12.0 Amps	14.0 Amps	144 Amp^2Sec	144 Amp^2Sec
Step Motor	8.0 Amps	9.0 Amps	149 Amp^2Sec	149 Amp^2Sec

Setting continuous current limit and energy limit to less than the maximum supported by the Atlas is useful if the current limit is due to the motor, or to some other factor external to Atlas.

4.7.9.1 Current Foldback in Voltage Mode

Atlas unit's current foldback mechanism still operates when Atlas is in voltage mode (current loop disabled). When in this mode, the I^2t energy calculations and condition testing are identical as when Atlas is operating in current control mode.

Nevertheless, when in voltage mode, there is an important operational difference. In particular, if the limit is exceeded, rather than clamping the maximum current output to the programmable maximum continuous current limit setting, Atlas disables the power stage module, thereby halting further motor output.

4.7.9.2 Example I^2t Calculations

The following example may help illustrate use of current foldback:

A particular motor has an allowed continuous current rating of 3 amps. In addition, this motor can sustain a temporary current of 5 amps for 2 seconds.

In this example the continuous current limit would be set to 3 amps, and the energy limit would be set to:

Energy Limit = (peak current^2 - continuous current limit^2) * time

Energy Limit = ($5A^2$ - $3A^2$) * 2 Sec

Energy Limit = $32A^2$Sec

Current foldback, when it occurs, may indicate a serious condition affecting motion stability, smoothness, and performance. It is the responsibility of the user to determine the appropriate response to a current foldback event.

4.7.9.3 Current Foldback Event Processing

Atlas provides a programmable mechanism related to the current foldback condition. This can be useful for tailoring the response of the Atlas to best suit a specific application.

The Atlas facility that handles this type of programmable response is called an event. Events allow event actions to be executed automatically once a specified condition occurs. In this case, the event condition is satisfied if Atlas is in a current foldback condition, and the following table describes the event actions that can be selected by the external controller:

Action Name	Description
No Action	No event-related action taken, current limited to continuous current limit
Disable power stage and current loop	Disables the power stage and the current loop module

If a foldback event occurs when Atlas is in voltage mode (current loop not enabled), then the power stage will be disabled regardless of the setting of the event action.

The default action for the current foldback event is to disable the power stage and current loop.

4.8 Step Motor Control

While many aspects of Atlas operation are similar between step motors and Brushless DC or DC Brush motors, Atlas provides a number of special features for supporting step motors. This section describes these special step motor-specific features.

Overall, Atlas provides two step-motor specific position command methods. These are summarized in the table below:

Position Command Mode	Description
Pulse & direction signal input	Atlas directly supports input of hardware *Pulse*, *Direction*, and *AtRest* signals to interface with traditional external controllers that provide these signals. When operated in this mode, SPI communication is not available.
SPI pulse & direction	This pulse & direction interface utilizes the external controller SPI interface to provide continuous position information to Atlas. Compared to pulse & direction signal input, this approach allows full use of the SPI communication interface. Note that this is the standard mode used when a Magellan motion processor serves as the external controller.

4.8.1 Pulse & Direction Signal Input Mode

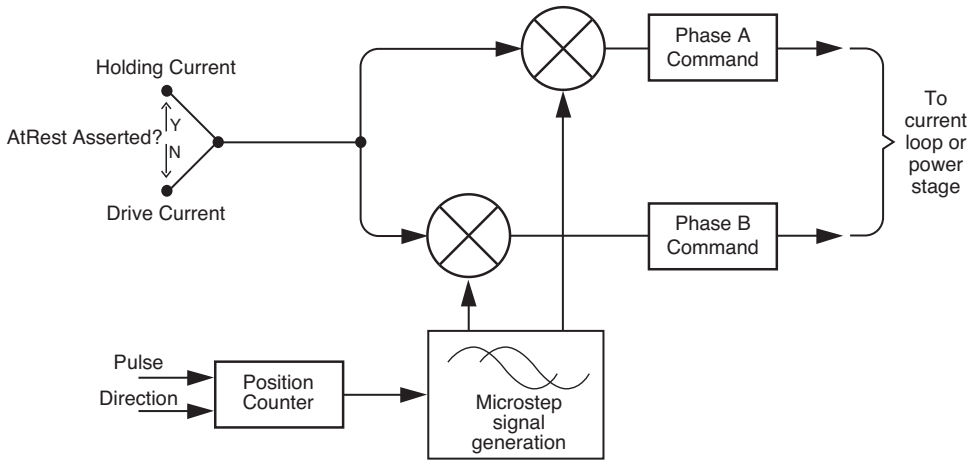


Figure 4-10: Pulse and Direction Signal Input Mode Control Flow

Figure 4-10 shows the control flow of the Atlas when used in pulse & direction signal input mode. The Atlas ***Pulse*** signal drives a counter which increments or decrements a step motor command position based on the state of the ***Direction*** signal. Pulse signals are expected to be active low, meaning that a position increment or decrement occurs when this signal transitions from high to low. The ***Direction*** signal indicates that a pulse received while the ***Direction*** signal is low is interpreted as a negative direction command, and a pulse received while this signal is high as a positive direction command.

Atlas provides programmable microstepping resolution, which means that the incoming position data stream can be interpreted by the Atlas at various resolutions. The maximum is 256 microsteps per full step, and the default interpretation is 64 microsteps per full step. This means that in the default condition, for a standard 1.8° two-phase stepper, Atlas provides a resolution of 12,800 microsteps per mechanical motor rotation, or roughly .028 degrees of mechanical motion per incoming pulse. Note that this control resolution may not equal the actual system accuracy.

When actually connected to Atlas in pulse & direction signal mode, SPI communication is not available.

4.8.1.1 Setting the Motor Current

When operating in pulse & direction input mode the current output by Atlas must be specified. Atlas supports two separate, programmable torques. The first is called the drive current and is used during normal step motor operations.

The second is called the holding current and is used when the motor is stationary as indicated by the *AtRest* signal. This signal is typically set when the external controller's trajectory generator completes its move or shortly thereafter. *AtRest* is an active low signal, meaning when no motion is occurring this signal should be is set low, and set high when motion is occurring.

4.8.1.2 Pulse & Direction Signal Mode Operation Setup

Because Atlas shares SPI bus signal pins with the *Pulse*, *Direction*, and *AtRest* pins it is not possible to operate the Atlas in the pulse & direction signal input mode while communicating via the SPI communication bus.

To resolve this, Atlas is first connected in SPI mode, and the SPI interface is used to optimize the motion control application during application development and to download desired drive parameters to Atlas unit's non-volatile initialization storage memory. See Section 4.11, "Power-up & Non-Volatile Initialization Storage" for more information on non-volatile initialization storage.

Atlas is then switched to pulse & direction signal input mode, and this mode change is stored into non volatile initialization storage memory so that upon the next power up Atlas will operate in pulse & direction signal mode.

4.8.1.3 Recovering from Pulse & Direction Signal Mode

It is possible to restore an Atlas that is functioning in pulse & direction signal mode to SPI operation. While this is an uncommon operation, it may be useful for testing, diagnosing a field problem, or to allow a production Atlas to be used for prototyping with optimization software such as PMD's Pro-Motion software. Refer to the *Atlas Digital Amplifier Complete Technical Reference* for details on how this recovery is accomplished.

4.8.1.4 Fault Processing While in Pulse & Direction Signal Input Mode

In order to allow recovery from safety-related faults such as overtemperature or current foldback while operating in pulse & direction signal input mode, an automatic recovery mode is available. While this mode is most often used when in pulse & direction signal input mode, it may in fact be selected even when SPI communications are available.

While in automatic recovery mode the *Enable* signal is used to request that the Atlas automatically attempt to reset a fault condition. After the *FaultOut* signal goes active, the external controller must delay a minimum of 150 uSec, but thereafter may request that the Atlas attempt to automatically recover by deasserting, and then asserting, the *Enable* signal. The *Enable* signal must be in the deasserted state for at least 150uSec for the request to be recognized.

When an automatic recovery request is recognized by Atlas, if the fault condition is still present when recovery is attempted, Atlas will immediately again disable itself, and a recovery procedure must once again be requested. If the fault has been corrected however, a recovery request will result in resumption of normal Atlas operation.

4.8.2 SPI Pulse & Direction Mode

The SPI pulse & direction mode allows emulated pulse & direction information to be transmitted via the SPI bus. In this mode an incremental signed move distance is specified via the SPI command protocol at each external controller command. For example, a value of +7 specified by the external controller means the Atlas will move the step motor position forward 7 microsteps, and a command of -3 will cause the Atlas to move the step motor position backwards 3 microsteps.

To accommodate the *AtRest* signal, the SPI protocol incorporates a bit which is utilized by Atlas in the same manner as the *AtRest* signal when in the hardware pulse & direction mode. See the *Atlas Digital Amplifier Complete Technical Reference* for a complete description of the SPI command format.

As was the case for pulse & direction signal mode, both a drive current and a holding current should be specified when using the SPI pulse & direction mode.

4.8.3 Current Control with Step Motors

Current control when driving step motors occurs using either field-oriented control or independent phase control. See Section 4.4.2, "Field Oriented Control" for a detailed description of field-oriented control, and see Section 4.4, "Current Loop" for a detailed description of the Atlas unit's current loop.

4.9 User Memory Space & Buffers

Start Address (in Hexadecimal)	Function
0X0000 0000	Trace RAM (1,020 words)
0X0000 03FD	Reserved
0X2000 0000	NVRAM (1,024 words)
0X2000 0400	Reserved

Figure 4-11: User Memory Space and Buffers

Atlas provides the ability to store or retrieve data from a User Memory Space. Figure 4-11 shows the user memory space for Atlas. There is a trace area, and an area that is used to store non-volatile setup commands that can be read back by the external controller. See Section 4.10, "Trace Capture" for more information on trace. See Section 4.11, "Power-up & Non-Volatile Initialization Storage" for more information on setup command storage.

Atlas provides access to the user memory space via a mechanism known as a buffer. Atlas allows up to four different buffers to be defined, allowing the overall user memory space to be partitioned in a manner most useful to the external controller. Typically, there will just be two buffers, one for the trace area, and one for the setup area. However this additional flexibility may be useful for storing temporary application specific data, or to set up multiple trace data storage areas.

Buffers describe a contiguous block of memory and are defined by specifying a base address for the memory block and a block length. Once a buffer's base address and length have been defined, data values may be written to and read from the buffer.

Refer to the *Atlas Digital Amplifier Complete Technical Reference* for a detailed description of Atlas buffer management.

4.10 Trace Capture

Trace capture is a powerful Atlas feature that allows parameters and registers to be continuously captured and stored to the user memory space. The captured data may later be downloaded by the external controller using standard memory buffer access commands. Data traces are useful for optimizing current loop performance, diagnosing SPI communications, capturing signal data, or assisting with any type of monitoring where a precise time-based record is required.

Broadly speaking, there are three phases associated with data trace operations. In the first phase, the external controller specifies which parameters will be captured, and how the trace will be executed. In the second phase, Atlas captures the trace data. This can occur autonomously, or under external controller control. Finally, in the third phase the external controller retrieves the data. This can occur after the trace is complete, or concurrently with capture.

4.10.1 Trace Parameters

To start a trace the external controller must specify a number of parameters. They are:

Parameter	Description
Trace buffer	The external controller must initialize and specify the memory buffer that will be used for the trace data storage area. See Section 4.9, "User Memory Space & Buffers" for more information on buffers.
Trace period	Atlas can capture the value of the trace variables for every single time cycle, every other cycle, or at any programmed frequency. This trace period of data collection and storage must be specified.
Trace variables	There are dozens of separate variables and registers within Atlas that may be traced; for example, the phase A current command, the current loop error, etc… The user must specify the variables that will be traced by Atlas.
Trace mode	Atlas can trace in one of two modes: one-time, or rolling mode. This determines how the data is stored, and whether the trace will stop automatically or be stopped explicitly by the external controller.
Trigger mode	Atlas supports two different methods for determining the moment when data capture actually occurs. The first is internally, via the Atlas unit's internal clock cycle and the trace period defined above. The second is externally commanded by the external controller via the SPI communication protocol. See Chapter 5, "SPI Communications" for more information on the SPI protocol. Note that when external trigger mode is selected the trace period is not used.
Trace Start/Stop	Atlas allows the external controller to control when trace capture starts and stops. Two overall conditions are supported; starting and stopping immediately via a command or via the trace bit of the SPI communication header.

4.10.1.1 Trace Variables

When traces are running one to four Atlas parameters may be stored to the trace buffer for each occurrence of the trigger. The four trace variable registers are used to define which parameters are stored.

The following table shows all of the Atlas variables that can be traced along with the variable ID code that is used to select this variable for tracing.

Variable ID	Name	Description
Status Registers		
12	Event Status	The Event Status register
14	Signal Status	The Signal Status register
56	Drive Status	The Drive Status register
79	Drive Fault Status	The Drive Fault Status register
80	SPI Status	The SPI Status word
Commutation/Phasing		
7	Active Motor Command	The external controller-commanded voltage or torque command
17	Phase A Command	The output command for phase A
18	Phase B Command	The output command for phase B
19	Phase C Command	The output command for phase C
29	Phase Angle Scaled	The phase angle, scaled from 0 to 360° rather than in encoder counts.
Current Loop		
66	Phase A Reference	The current loop reference for Phase A
67	Phase B Reference	The current loop reference for Phase B
30	Phase A Error	The current loop error for Phase A
35	Phase B Error	The current loop error for Phase B

Variable ID	Name	Description
31	Phase A Actual Current	The current loop actual current for Phase A
36	Phase B Actual Current	The current loop actual current for Phase B
33	Phase A Integrator Contribution	The current loop integrator contribution for Phase A
38	Phase B Integrator Contribution	The current loop integrator contribution for Phase B
34	Phase A Current Loop Output	The current loop output for Phase A
39	Phase B Current Loop Output	The current loop output for Phase B
Field Oriented Control		
40	d Reference	The FOC reference for d (direct) loop
46	q Reference	The FOC reference for q (quadrature) loop
41	d Error	The FOC d (direct) loop error
47	q Error	The FOC q (quadrature) loop error
42	d Feedback	The d (direct) feedback current
48	q Feedback	The q (quadrature) feedback current
44	d Integrator Contribution	The FOC integrator contribution for d (direct)
50	q Integrator Contribution	The FOC integrator contribution for q (quadrature)
45	d Output	The FOC output for d (direct)
51	q Output	The FOC output for q (quadrature)
52	FOC phase A Output	The FOC output for phase A
53	FOC phase B Output	The FOC output for phase B
73	Alpha Current	The FOC α current component (stationary frame)
74	Beta Current	The FOC β current component (stationary frame)
31	Phase A Actual Current	The FOC actual current for phase A
36	Phase B Actual Current	The FOC actual current for phase B
Motor Output		
54	Bus voltage	The bus voltage
55	Temperature	The temperature of Atlas
68	I^2t Energy	Accumulated I^2t foldback energy
75	Terminal A Output	The PWM duty cycle for terminal A
76	Terminal B Output	The PWM duty cycle for terminal B
77	Terminal C Output	The PWM duty cycle for terminal C
69	Leg Current A	The measured current in lower leg A
70	Leg Current B	The measured current in lower leg B
71	Leg Current C	The measured current in lower leg C
72	Leg Current D	The measured current in lower leg D
78	Clip Factor	Actual output as a fraction of commanded output
Miscellaneous		
0	None	No trace variable is selected
8	Atlas Time	Atlas unit's processor time in units of cycles

For further information on how to set up, control and download traces, refer to the *Atlas Digital Amplifier Complete Technical Reference.*

4.11 Power-up & Non-Volatile Initialization Storage

After receiving stable power at the HV pins Atlas begins its initialization sequence.

In a power-up where no user-provided initialization parameters have been stored this takes approximately 250 mSec. At the end of this sequence all parameters are at their default values, and both the current loop module and the power stage module are disabled. At this point Atlas is ready to receive commands and begin operation.

4.11.1 Power-up with Non-Volatile Initialization Storage

Atlas supports a 1,024 word memory segment that is non-volatile (NVRAM), meaning the data stored will be available even after power to the Atlas is removed.

Figure 4-11 shows the user memory space and the location of the NVRAM segment. The primary purpose of the NVRAM is to allow Atlas configuration information to be stored, so that upon power up it can be automatically loaded rather than requiring an external controller to perform this configuration initialization function.

The configuration information stored in the NVRAM takes the form of Atlas command packets, however rather than being sent via SPI, these packet words are stored in memory. If the non-volatile initialization memory has been loaded with information the power-up sequence detects this and begins executing the commands stored in the non-volatile memory. Note that processing stored commands may increase the overall initialization time depending on the command sequence stored.

If there are errors in the stored command sequence then an instruction error will be loaded so that the error can later be diagnosed. Atlas will abort initialization if it detects any error while processing commands.

4.11.2 Initialization Storage Format

Atlas parameter data stored into NVRAM for initialization is formatted exactly as if it were being sent by the external controller using the SPI protocol during normal SPI operations. See the *Atlas Digital Amplifier Complete Technical Reference* for more information on the format of Atlas commands.

4.11.3 Using NVRAM as General Purpose Memory

There may be situations where it is convenient for the external controller to utilize the Atlas unit's non-volatile memory for its own parameters or data. Atlas supports this, however there are some restrictions.

Such data must be stored at the end of the initialization command sequence. In addition, the first data word of such a memory sequence must be stored after a separator sequence consisting of four consecutive 0xffff words. Refer to the *Atlas Digital Amplifier Complete Technical Reference* for details.

4.12 SPI Communications Overview

Atlas uses an SPI (Serial Peripheral Interface) digital connection to communicate with the external controller. This connection is used to setup Atlas parameters, specify voltage or torque output values, monitor Atlas operation, as well as other functions.

SPI is a convenient interface because it is available on many microprocessors, provides relatively high speed communications, and uses only 4 signals; SPIClk (Clock), SPICS (chip select), SPISI (slave in), and SPISO (slave out).

Atlas utilizes standard SPI signaling and timing control for the hardware interface and implements a higher level protocol on top of this. See Section 3.6, "AC Characteristics" to learn more about low-level hardware SPI signal timing, voltage levels, etc.

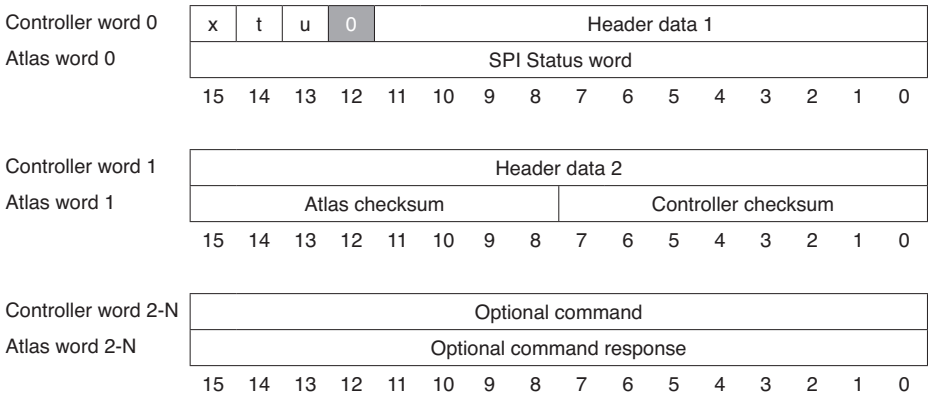

Controller word 0
Atlas word 0
x
t
u
0
Header data 1
SPI Status word
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
Controller word 1
Atlas word 1
Header data 2
Atlas checksum
Controller checksum
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
Controller word 2-N
Atlas word 2-N
Optional command
Optional command response
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

Figure 4-12: SPI Communications Protocol Overview

All communications to and from Atlas are in the form of a packet. Figure 4-12 shows the overall packet format. A falling edge of the chip select begins the packet, and a rising edge of the chip select ends the packet. All Atlas SPI packets are comprised of a two word header and one or more optional command words.

4.12.1 Packet Header

The first two words of the packet are called the header and are used to specify a desired motor voltage or torque along with certain other functions such as when a trace starts and when a command update should occur.

Here is a detailed description of the Atlas packet header:

Field	Bit	Name	Description
data 1	0-11	Header data 1	Holds various data, the format of which depends on the state of the Torque data flag.
	12	Reserved	This field is reserved, and should be loaded with a 0.
u	13	Update flag	A 0 in this field means that a buffered command update is not commanded. A 1 in this field results in an update of all buffered parameters.
t	14	Trace active flag	This field controls various trace-related activities. See Section 4.10, "Trace Capture" for details. A 0 in this field means that trace is not active. A 1 signals that a trace is active, or that a capture is requested.
x	15	Torque data flag	A 0 in this field means the header will contain a desired voltage or torque output value. A 1 means that it will contain a request for a disable operation or a NOP operation.
data 2	0-15	Header data 2	Holds various data, the format of which depends on the state of the Torque data flag.

The 'x' bit field affects the format of other fields, in particular the data 1 and data 2 fields. Therefore care should be taken to correctly select the value of this field and associated data 1 and data 2 fields.

The 't' and the 'u' bit-fields do not affect the format of other fields, and may be set to any value at any time as desired by the external controller. These fields are a means for the external controller to synchronize activities for trace and update-related functions of Atlas. See Section 4.10, "Trace Capture" for more information on use of the trace active flag.

4.12.1.1 Header Return Words

As shown in Figure 4-12 each SPI word sent from the external controller to Atlas results in a return word sent from Atlas to the external controller. In fact at a signal level, each outgoing bit is sent simultaneously with each incoming bit, providing full duplex communications.

The external controller must receive and process data words sent to it by Atlas. These return words, depending on the context, contain transmission integrity information, status bits, or other useful information.

The table below provides the contents of the data words returned by Atlas during header SPI transmissions.

Field	Description
SPI Status word	Contains 16 bits of drive status, signal status, and event information that can be monitored by the external controller.
Atlas checksum	Atlas checksum is the 8 bit, ones-complement checksum of four bytes: the low byte of SPI Status Word, the high byte of SPI Status Word, the Controller Checksum byte (see next field), and the byte value 0xAA.
Controller checksum	Controller checksum is the 8 bit, ones-complement checksum of five bytes: the low and high bytes of both previously received header words and the byte value 0xAA.

4.12.2 Sending a Voltage or Torque Output Value

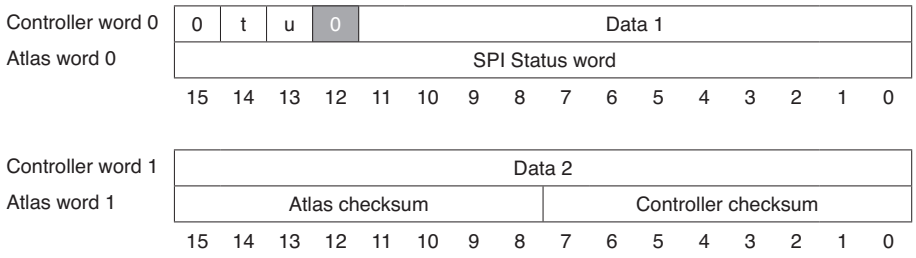


Figure 4-13: Sending a Voltage or Torque Output Value

Generally the most frequently used header transaction is an instantaneous voltage or torque output request for output by the drive. If Atlas is used as part of a higher level velocity or position controller, then these values are continuously sent to Atlas at the servo sampling speed of the main motion controller, typically between 1 kHz and 10 kHz.

Figure 4-13 shows the overall format of the header words when voltage or torque commands are being sent. Depending on the motor type and command mode being used the data words will be loaded one of several different ways.

For a complete description of these fields, along with many other details of Atlas SPI operation, refer to the *Atlas Digital Amplifier Complete Technical Reference*.

A.Atlas Developer's Kit

A

In This Appendix

- Overview
- Installation and Getting Started
- Atlas Carrier Card Reference Information
- L-Bracket

A.1 Overview

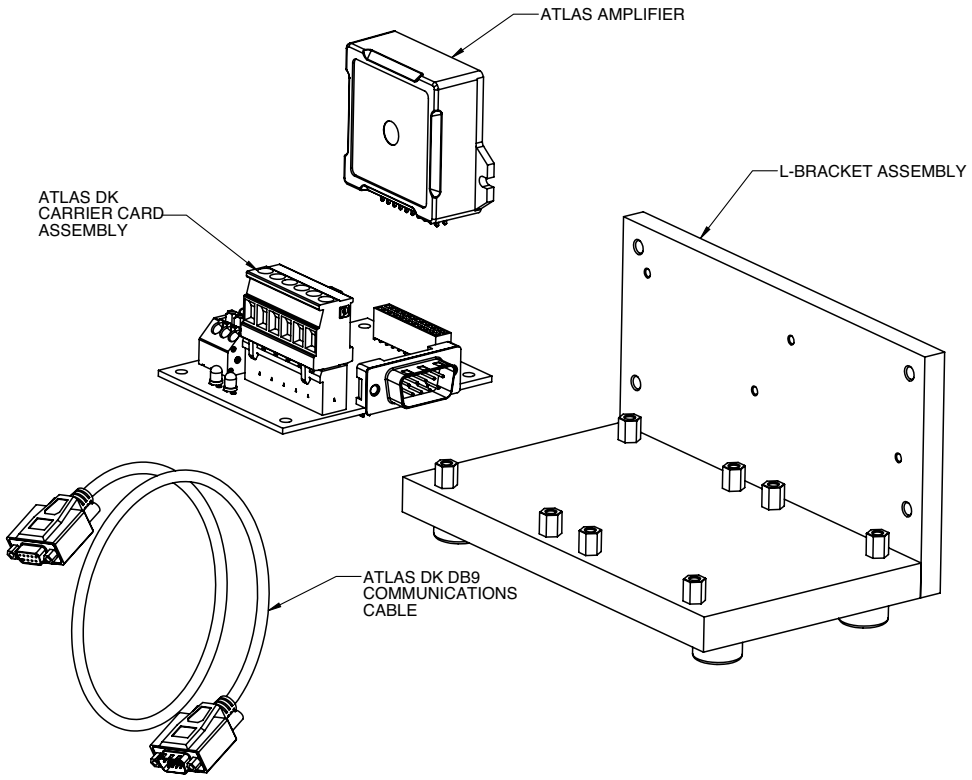


Figure A-1: Developer Kit Components

To simplify development with Atlas Amplifiers Developer's Kit (DK) is available.

In addition to documentation and software distribution media, the major elements of the DK are:

- Atlas carrier card
- Atlas DK DB9 communications cable
- Optional L-bracket base and vertical member for heat sink attachment with associated mounting hardware (comes in 1, 2, or 4 axis version)

The L-bracket is optional but highly recommended because it provides a stable mechanical base from which you can connect and operate your prototype system. With the vertical plate option installed the Atlas units have additional heat sinking, which can be extended further by connecting the vertical plate to your own heat sink or cold plate.

A.2 Installation and Getting Started

In these instructions it is assumed that you have purchased a Magellan DK (Developer's Kit), which comes with the Pro-Motion exerciser and tuning software. If you have not purchased a Magellan DK then you will still find these instructions useful, however you will use the detailed connections detailed in Section A.3, "Atlas Carrier Card Reference Information," to connect your system and begin operation.

A.2.1 Setting Atlas SPI Bus Addresses

If your Atlas DK came with an L-bracket, the Atlas units are pre-loaded on the L-bracket hardware and each Atlas is pre-addressed with axis number labeled. You can therefore skip to Section A.2.2, "SPI Bus Connections," of these getting started instructions.

If you are not using an L-bracket, you will need to set the SPI bus address using jumper J6 on each Atlas carrier card.

For vertical Atlas units you can set the jumper without removing the Atlas from the carrier card. For horizontal Atlas units you must remove Atlas from the socket, select a jumper, and then carefully remount the Atlas into the socket.

Refer to Figure A-2 to select an address.

Each Atlas must have a unique address from 1 to 4, and this number directly corresponds to the axis number addressed by the Magellan Motion Processor.

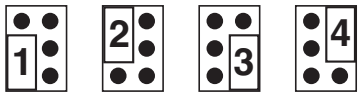


Figure A-2: Setting ATLAS SPI Bus Addresses

A.2.2 SPI Bus Connections

If you are using an L-bracket you should plug in the provided 12" DB9 cable at J5, the female DB9 connection of the carrier card. Do not plug in at the male DB9 connection, J4. Doing so will mean that you will not be able to connect your Atlas units to the Magellan DK card. Once you have plugged in the DB9 cable, you can skip forward to Section A.2.3, "Motor Connections," and continue from there.

The DB9 connections used with the Atlas DK are not compatible with standard RS232 serial ports. Do not attempt to plug this connector directly into your PC.

If you did not order an L-bracket, you will need to first connect the Atlas units together, and then connect the provided 12" cable.

Connecting Atlas units together is easily accomplished by plugging them directly into each other in a chain, without any intervening cable at the J5 (female) and J4 (male) DB9 connections. Up to four Atlas units can be plugged together in this manner. Once this has been accomplished, the male end of the 12" DB9 cable should be connected at the open Atlas carrier card J5 (female) connector. Note that there is no termination required for the opposite J4 (male) DB9 connector at the end of the chain. This connector is simply left unconnected. This is shown in Figure A-3.

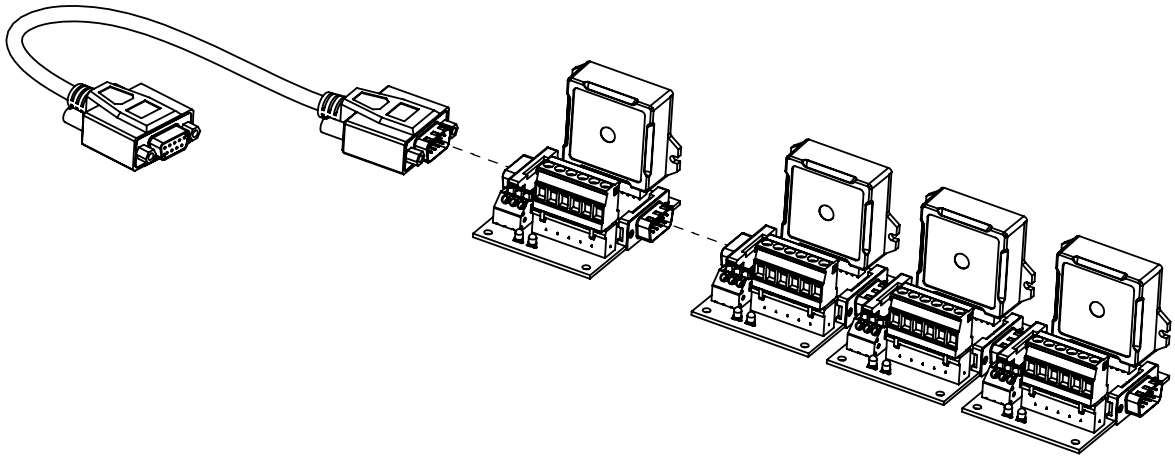


Figure A-3: Chain of DK Carrier Cards

When assembling the Atlas unit chain, the position in the chain has no bearing on the selected Atlas address. This address is determined entirely by the jumper. See Section A.2.1, "Setting Atlas SPI Bus Addresses," for a description. In assembling your own chain, you may therefore find it useful to label the carrier cards with an easily readable axis # to avoid confusion when connecting motors.

A.2.2.1 Connecting an Atlas Chain By Cables

There may be circumstances where you prefer not to connect all of the Atlas carrier cards directly to each other, but rather via cables. If this is the case, care should be taken not to exceed the total cable length specification for the SPI bus of 2.0 feet. This is the total length from the Magellan DK card connection point to the last Atlas in the chain including the length of the carrier cards and all connecting cables.

The maximum allowed SPI bus length is 2.0 feet. Exceeding this specificaiton may result in communication errors and unreliable Atlas operation.

The SPI bus is not designed to operate external modules by cable connection, and therefore in production applications it is recommended that Atlas units be located on the same printed circuit card. Regardless of where Atlas is located, it is the responsibility of the user to ensure that SPI signals are noise free and within Atlas unit's timing specifications.

A.2.3 Motor Connections

For each Atlas, connect the motor using the chart below and the J1 6-terminal jack screw plug on the carrier card. Use copper wire gauge 14AWG or larger to ensure that all current output requirements can be met.

Motor Type	Use Motor Connections	J1 Jackscrew Plug Labels
Brushless DC	Motor A, Motor B, Motor C	Mtr A, Mtr B, Mtr C
DC Brush	Motor A, Motor B	Mtr A, Mtr B
Step Motor	phase A: Motor A, Motor B phase B: Motor C, Motor D	Mtr A, Mtr B, Mtr C, Mtr D

A.2.4 Power Connections

For each Atlas, connect the bus supply voltage (HV) and the associated return ground signal at the J6 jack screw plug. Once again, utilize AWG 14 or larger to ensure that full current demand can be met while operating the unit. The power signals are labeled +HV and GND.

For most installations you will use a single, common power supply to power all Atlas units. However this is not required. If desired, you can operate different Atlas units at different voltages by connecting to different DC supplies.

While connecting power signals make sure that the power supply is off.

A.2.5 Enable Signal Connection

You must provide an 'active' enable signal to allow Atlas to operate. There are a few options to accomplish this, depending on how you plan to operate your system. The simplest approach is to use a short piece of AWG 20 or larger wire to connect the GND signal of jackscrew plug J2 to the Enable input (labeled ~Enab).

For safety reasons, you may prefer to wire the enable input into a separate switch or E-stop button. Regardless of how it is accomplished, the enable signal must be driven active (low) for Atlas to operate.

A.2.6 Installing and Connecting to the Magellan DK Card

To set up and install the Magellan DK card refer to the *Magellan Motion Processor Developer's Kit Manual.* This manual will help you select jumper settings and make connections to the motor's encoders and other connections.

To install Atlas DKs to the Magellan DK connect the SPI bus cable to the Magellan DK card via the DB9 cable to J14 of the Magellan DK card.

Once all connections have been made you should power up the PC (but not the Atlas units) and follow the manual's direction for installing Pro-Motion software. You can run Pro-Motion, check for encoder feedback, etc…. but for axes that utilize Atlas amplifiers, motor output will not yet be operational.

A.2.7 Powering Up the Atlas Units

Once all connections are made and Pro-Motion is installed and running you are ready to provide power to the Atlas units.

Upon doing so verify that there is no motor movement, all power LEDs are lit, and none of the fault out LED indicators are lit. If any of these conditions is not true, power the Atlas units down and recheck connections.

Once a normal power-up is achieved the Atlas units are ready for operation. You may now use Pro-Motion's Axis Wizard to install and operate your motors, or perform direct manual operations using Pro-Motion's various control menus.

Congratulations! You have successfully installed the Atlas DK.

A.3 Atlas Carrier Card Reference Information

The following sections provides detailed information on the electrical characteristics of the Atlas DK carrier card.

There are two different designs of carrier card, one for the vertical Atlas units and one for horizontal units. Electrically these two cards are similar, differing only in the socket connections to the Atlas unit.

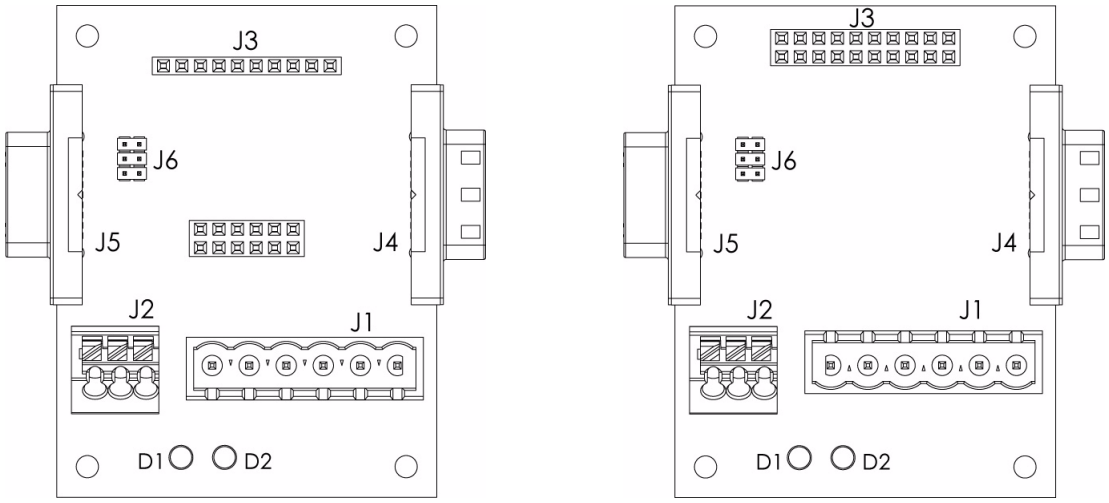


Figure A-4: Top Outline View of Horizontal and Vertical DK Card

A.3.1 J1 & J2 Jack Screw Connectors

J1 and J2 provide jack screw-style connections to various Atlas signals. The following table shows this:

J1 Connector		
Carrier Card Label	**Name**	**Description**
Mtr D	Motor D	D Motor connection
Mtr C	Motor C	C Motor connection
Mtr B	Motor B	B Motor connection
Mtr A	Motor A	A Motor connection.
GND	Mtr_Gnd	Ground return for Motor and HV
+HV	HV	Motor supply voltage

J2 Connector		
Carrier Card Label	**Name**	**Description**

~Enab	Enable	Enable input
Flt	FaultOut	FaultOut output
GND	GND	Ground return for *Enable* and *FaultOut* signals

A.3.1.1 Quick Connect Motor Type Chart

Motor Type	Connections
Brushless DC	Motor A, Motor B, Motor C
DC Brush	Motor A, Motor B
Step Motor	phase A: Motor A, Motor B phase B: Motor C, Motor D

A.3.2 J4 & J5 DB9 Connectors

A.3.2.1 SPI Communications

J4 and J5 are used to provide SPI communications between multiple Atlas DK cards and a Magellan DK card or the user's motion control system. J5 is female, and J4 is male. This arrangement facilitates connection of multiple Atlas units in a direct physical chain.

Here are the pinouts for J4 & J5 when used for SPI communications

J4 & J5 Connector		
Pin	**Name**	**Description**
1	~SPICS3	SPI chip select for Atlas #3
2	~SPICS2	SPI chip select for Atlas #2
3	Shield	Cable shield connection
4	GND	Ground
5	SPISO	SPI Slave Out
6	~SPICS1	SPI chip select for Atlas #1
7	~SPICS4	SPI chip select for Atlas #4
8	SPIClk	SPI Clock
9	SPISI	SPI Slave In

A.3.2.2 Pulse & Direction Mode

J4 or J5 are also used to provide pulse & direction signals to a single Atlas. In this mode, multiple Atlas DKs can not be connected to each other and the J6 address selector jumper should be set to an address of 1.

In this mode either J4 or J5 may be used for connection, the only difference being the gender of the connector.

Here are the pinouts for J4 & J5 when used in pulse & direction signal mode

J4 & J5 Connector		
Pin	**Name**	**Description**
1	not used	
2	not used	
3	Shield	Cable shield connection
4	GND	Ground
5	not used	
6	AtRest	Pulse & direction mode *AtRest* signal
7	not used	

8	Pulse	Pulse & direction mode *Pulse* signal
9	Direction	Pulse & direction mode *Direction* signal

A.3.3 J6 Address Selector

J6 is a jumper that programs the address of a particular carrier card when using the SPI bus. The carrier card backplane supports up to four separate Atlas units via four individual chip select signals. To communicate to a particular carrier card, the external controller's chip select signal must match the address selected via this jumper.

Figure A-5 shows how this jumper is programmed to select addresses 1 through 4.

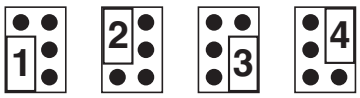


Figure A-5: J6 Address Selector

A.3.4 Atlas Connections

The carrier cards connect to the Atlas unit via sockets at J3. The tables below show the Atlas connections for these connectors

A.3.4.1 Vertical Unit Connections

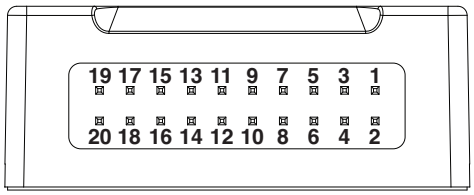


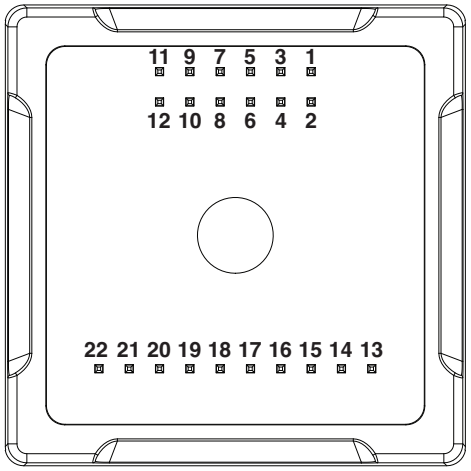
Figure A-6: Vertical Unit Pinouts

Pin	Name	Pin	Name
1	Pwr_Gnd	2	Pwr_Gnd
3	HV	4	HV
5	Motor A	6	Motor A
7	Motor B	8	Motor B
9	Motor C	10	Motor C
11	Motor D	12	Motor D
13	~Enable	14	FaultOut
15	5V	16	GND
17	~SPICS/AtRest	18	SPISI/Direction
19	SPIClk/Pulse	20	SPISO

The pins are 0.1 inch spacing and 0.025 inch pin width.

A.3.4.2 Horizontal Unit Connections

Figure A-7: Horizontal Unit Pinouts



Pin	Name	Pin	Name
1	Motor D	2	Motor D
3	Motor C	4	Motor C
5	Motor B	6	Motor B
7	Motor A	8	Motor A
9	HV	10	HV
11	Pwr_Gnd	12	Pwr_Gnd
13	5V	14	GND
15	~Enable	16	FaultOut
17	GND	18	~SPICS/AtRest
19	SPISO	20	SPISI/Direction
21	SPIClk/Pulse	22	GND

The pins are 0.1 inch spacing and 0.025 inch pin width.

A.3.5 LED Indicators

The Atlas DK carrier card has two LEDs. The green LED, when lit, indicates that Atlas is receiving valid power input power at HV. The red LED, when lit, indicates that an Atlas FaultOut condition is active.

A.4 L-Bracket

The Atlas DK can be ordered with L-brackets that provide extra mechanical stability and heat sinking during prototyping. Depending on the type of Atlas that you are using, you may use just the base plate or the base plate and vertical plate in the "L" configuration.

L-bracket hardware is available in a one axis configuration, two axis configuration, and four axis configuration.

Normally, the Atlas units and carrier cards are fully assembled into the L-brackets. If you ordered your DK components not assembled however, you can assemble these components yourself. To assist with this, an assembly

drawing is shown in Figure A-8. All needed assembly components should be included with the shipment. In addition, you will need 1.5 mm and 2 mm hex wrenches to assemble the carrier cards, Atlas units, and L-bracket together.

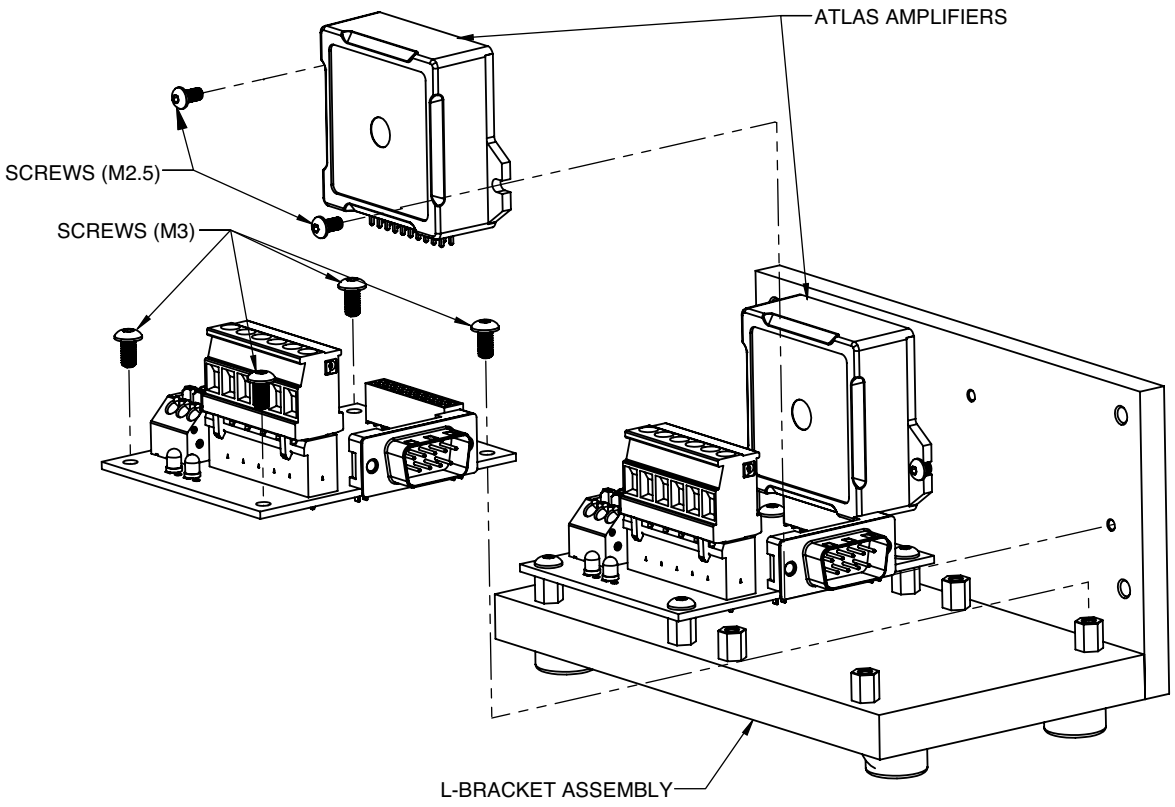


Figure A-8: Mounting Atlas to Vertical Plate

A.4.1 Mounting Atlas to Vertical Plate

For vertical units with mounting tabs, two M2.5 BHCS (Button Head Cap Screws) or similar are used to attach the Atlas unit to the vertical plate, assuming it has been included with the DK. This is shown in Figure A-8. While optional, mechanically connecting the Atlas units to the L-bracket is highly recommended to provide the best heat flow from the Atlas unit, and to increase the mechanical robustness of the development system.

For best thermal performance, a material such as Sil-Pad, thermal grease, or phase change material should be utilized between metal interfacing layers.

For horizontal units, and for vertical units without mounting tabs, the Atlas unit is seated in the carrier via a socket. No mechanical hardware is used to attach the Atlas.

A.4.2 Mounting L-bracket to Other Hardware

To maximize heat sinking capacity you may choose to mount the vertical L-bracket piece to your own hardware. For best thermal performance, a material such as Sil-Pad thermal grease or phase change material should be utilized between metal interfacing layers.

To connect to the vertical plate use four (4) M4 screws threaded into the provided threaded holes in the vertical plate or use four (4) M3 screws with nuts and washers to fasten through from the front.

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B.Application Notes

- Brushless DC Atlas With Single-Axis Magellan
- DC Brush & Step Motor Atlas With Multi-Axis Magellan
- Step Motor Atlas Operating In Pulse & Direction Mode
- DC Brush Atlas With PIC Microcontroller
- Step Motor Atlas With ARM Microcontroller

B.1 Brushless DC Atlas With Single-Axis Magellan

The following schematic shows a Brushless DC Atlas Amplifier connected to a single-axis Magellan.

B.1.1 Atlas Power Input and Motor Output

Atlas is powered through pin pairs HV and Pwr_Gnd, and the power source is a transformer-isolated DC power supply. When unregulated DC power supply is used the output voltage with respect to its output power/current should meet the full Atlas operating range specification. The power supply should be able to "absorb" the recovered energy when Atlas is in regeneration mode. If a regulated DC power supply is used, but it cannot dump the regenerated energy, a blocking diode between the power supply and HV can be used.

The Pwr_Gnd and GND pins are shorted inside the Atlas, and at a system level they refer to the same ground. Pwr_Gnd, the current return path for the power train, is paired with HV and may therefore be noisy. GND is the reference for the SPI signals and other digital control signals. These signals require a quiet ground reference. To ensure optimal performance, star grounding is recommended for component placement and layout. That is, Pwr_Gnd and GND should be connected to the system ground very close to Atlas, and the two ground paths should be kept away from each other.

There is a third current return path stemming from the high frequency component of the motor winding current. Atlas drives motor windings with pulse-width modulated (PWM) signals. Although the sum of the average winding currents is zero, the high frequency PWM signal may couple to the ground plane and induce noise into other circuits. Therefore, depending on your application, you may consider utilizing a motor shield cable to provide a current return path. If utilized, its ground point should be very close to, or the same, as Pwr_Gnd.

For Brushless DC motors pins MotorA, MotorB and MotorC are wired to motor windings A, B, C, respectively. Pins MotorD are left un-connected.

B.1.2 Atlas SPI Interface

Atlas receives control commands through an SPI interface and functions as an SPI slave. Atlas SPI communication is enabled when ~SPICS is pulled down.

To ensure optimal SPI communication, please consider the following layout recommendations:

1. Keep traces short and use 45 degree corners instead of 90 degree corners.

2 All SPI signal traces should be located next to a continuous ground plane, or if possible, between two continuous ground planes.

3 Keep traces away from other noisy and high speed signal traces. Alternatively, run ground traces along with these signals as a shield.

4 When multiple Atlas modules are used, keep the SPI signal stubs short.

Note that the Atlas Development Kit layout can be used as a layout reference.

B.1.3 Atlas ~Enable and FaultOut Signals

Atlas has one dedicated input signal, ~Enable, which must be pulled low for the Atlas output stage to be active.

FaultOut is a dedicated output. During normal operation it outputs low. When a fault occurs it will go into a high impedance state. In this example, FaultOut is pulled up by Vpullup through resistor R1. Vpullup can be up to 24V to meet the system requirement. For example, if the fault signal is wired to a 5V TTL input, Vpullup can be 5V.

B.1.4 Magellan MC58110 Configuration

In this schematic the SPI master is a single axis Magellan MC58110. Only the connections with Atlas are shown. For complete Magellan wiring, please refer to the MC58110 electrical specifications.

The MC58110 is configured to default to Atlas motor output by tying pin 7, OutputMode0, to ground. The MC58110 inputs encoder signals, implements motion control and commutation functions, and sends torque commands to Atlas through the SPI interface. Depending on the Magellan commutation method selected the feedback signals HallA, HallB, HallC and ~Index are optional.

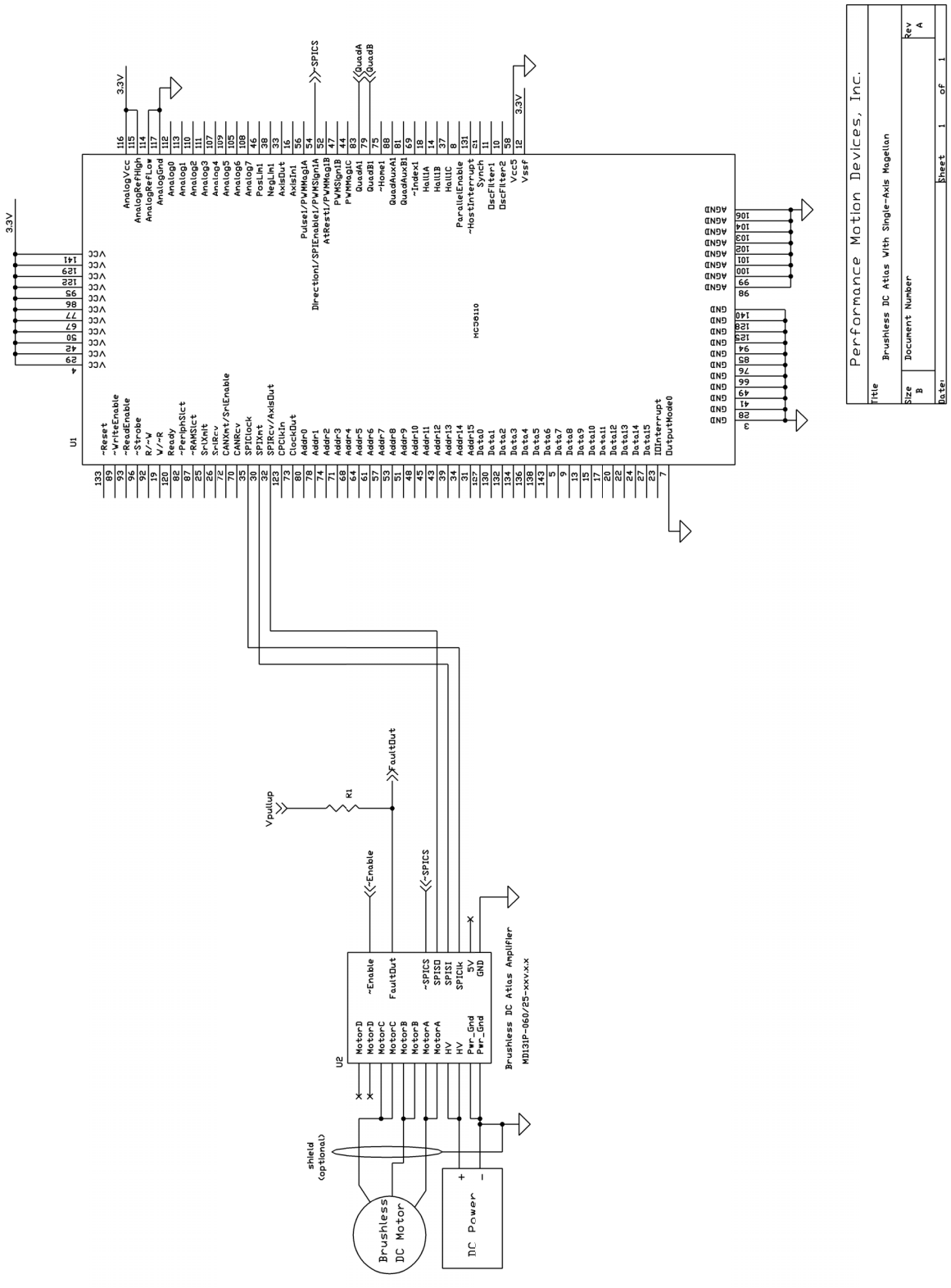

Figure B-1: Brushless DC Atlas With Single-Axis Magellan

B.2 DC Brush & Step Motor Atlas With Multi-Axis Magellan

The following schematic shows a two-axis application with one DC Brush Atlas Amplifier and one step motor Atlas amplifier controlled by a multi-axis Magellan.

B.2.1 Atlas Power Input and Motor Output

Atlas is powered through pin pairs HV and Pwr_Gnd, and the power source is a transformer-isolated DC power supply. In this application the two Atlases share the same power supply. Alternatively they could be powered independently so that different motor voltages could be used.

For DC Brush motors pins MotorA and MotorB are wired to motor windings Motor+ and Motor-, respectively. Pins MotorC and MotorD are left un-connected.

For step motors pins MotorA, MotorB, MotorC and MotorD are wired to motor windings A+, A-, B+ and B-, respectively.

Please refer to B.1 for layout and wiring recommendations on power input and motor outputs.

B.2.2 Atlas SPI Interface

Atlas receives control commands through an SPI interface and functions as an SPI slave. Atlas SPI communication is enabled when ~SPICS is pulled down. Only one Atlas can be enabled at any given time.

Please refer to B.1 for layout recommendation on SPI interface.

B.2.3 Atlas ~Enable and FaultOut Signals

Atlas has one dedicated input signal, ~Enable, which must be pulled low for the Atlas output stage to be active.

FaultOut is a dedicated output. During normal operation it outputs low. When a fault occurs it will go into a high impedance state. In this example, FaultOut is pulled up by Vpullup through resistor R1. Vpullup can be up to 24V to meet the system requirement. Each Atlas may use a different Vpullup voltage, for example, if the fault signal is wired to a 5V TTL input, Vpullup can be 5V.

B.2.4 Magellan MC58420 Configuration

In this schematic the SPI master is a four-axis Magellan MC58420. Only the connections with Atlas are shown. For complete Magellan wiring, please refer to the MC58420 electrical specifications.

The MC58420 is configured to default to Atlas motor output by tying pin 7, OutputMode0, to ground. In this example axis 2 and axis 3 are under control. The MC58420 sends torque commands to the DC Brush Atlas by pulling SPIEnable2 low, and sends position commands to the step motor Atlas by pulling SPIEnable3 low.

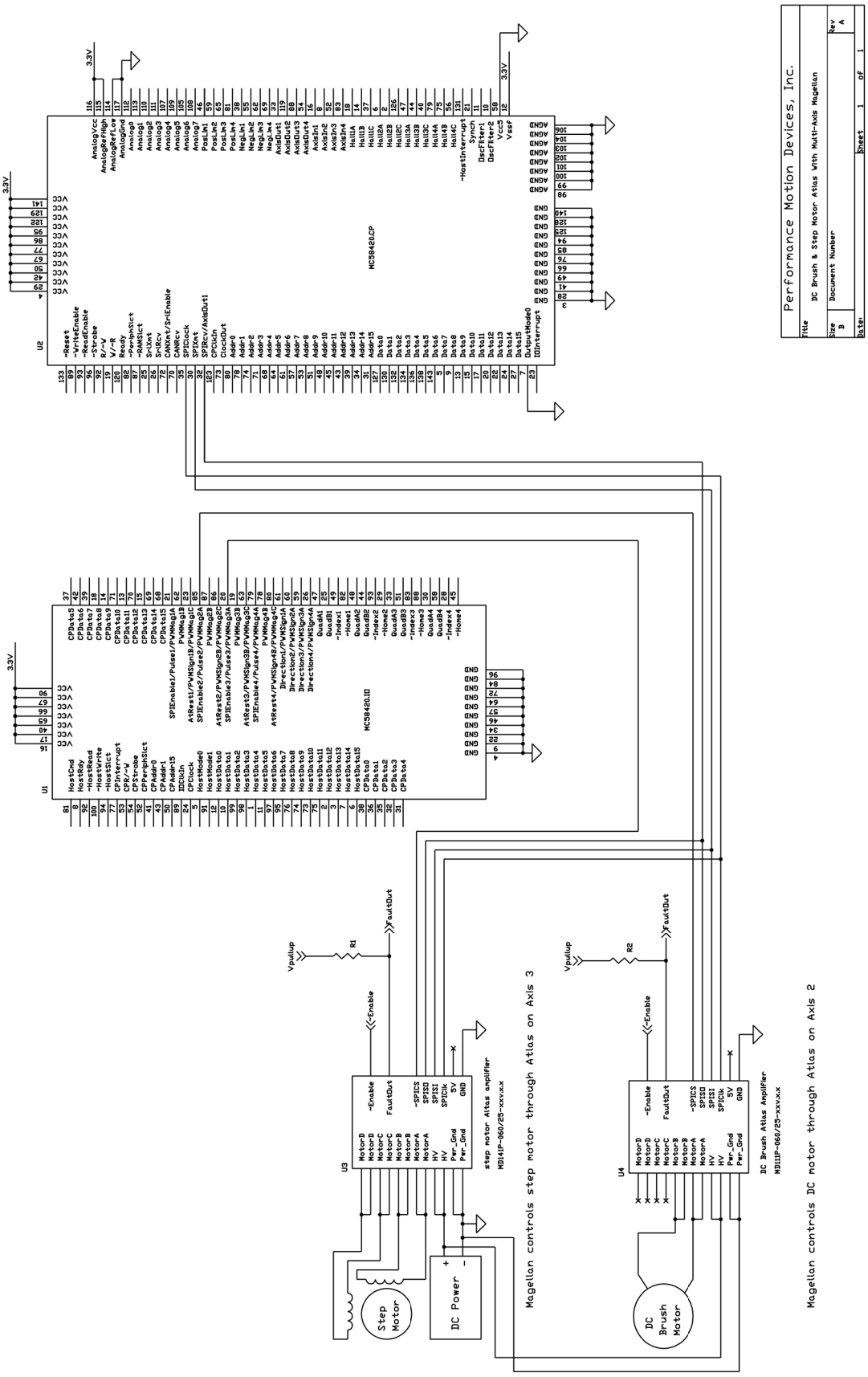

Figure B-2: DC Brush & Step Motor Atlas With Multi-Axis Magellan

B.3 Step Motor Atlas Operating In Pulse & Direction Mode

The following schematic shows Atlas operated in pulse & direction mode controlled by a single axis Magellan. Note that any source of pulse & direction signals, such as a microprocessor or other dedicated motion control IC, may be substituted for the Magellan in this schematic.

B.3.1 Atlas power input and motor outputs

Atlas is powered through pin pairs HV and Pwr_Gnd, and the power source is a transformer-isolated DC power supply.

For step motors pins MotorA, MotorB, MotorC and MotorD are wired to motor windings A+, A-, B+ and B-, respectively.

Please refer to B.1 for layout and wiring recommendations on power input and motor outputs.

B.3.2 Atlas Pulse & Direction Interface

When in pulse & direction signal mode, Atlas receives pulse, direction and AtRest signals as shown in the schematic. When operated in pulse & direction signal mode SPI communications are not available.

B.3.3 Atlas ~Enable and FaultOut Signals

Atlas has one dedicated input signal, ~Enable, which must be pulled low for the Atlas output stage to be active.

FaultOut is a dedicated output. During normal operation it outputs low. When a fault occurs it will go into a high impedance state. In this example, FaultOut is pulled up by Vpullup through resistor R1. Vpullup can be up to 24V to meet the system requirement. For example, if the fault signal is wired to a 5V TTL input, Vpullup can be 5V.

B.3.4 Magellan MC58110 configuration

In this schematic the SPI master is a single-axis Magellan MC58110 configured for pulse & direction signal output. Only the connections with Atlas are shown. For complete Magellan wiring, please refer to the MC581100 electrical specifications.

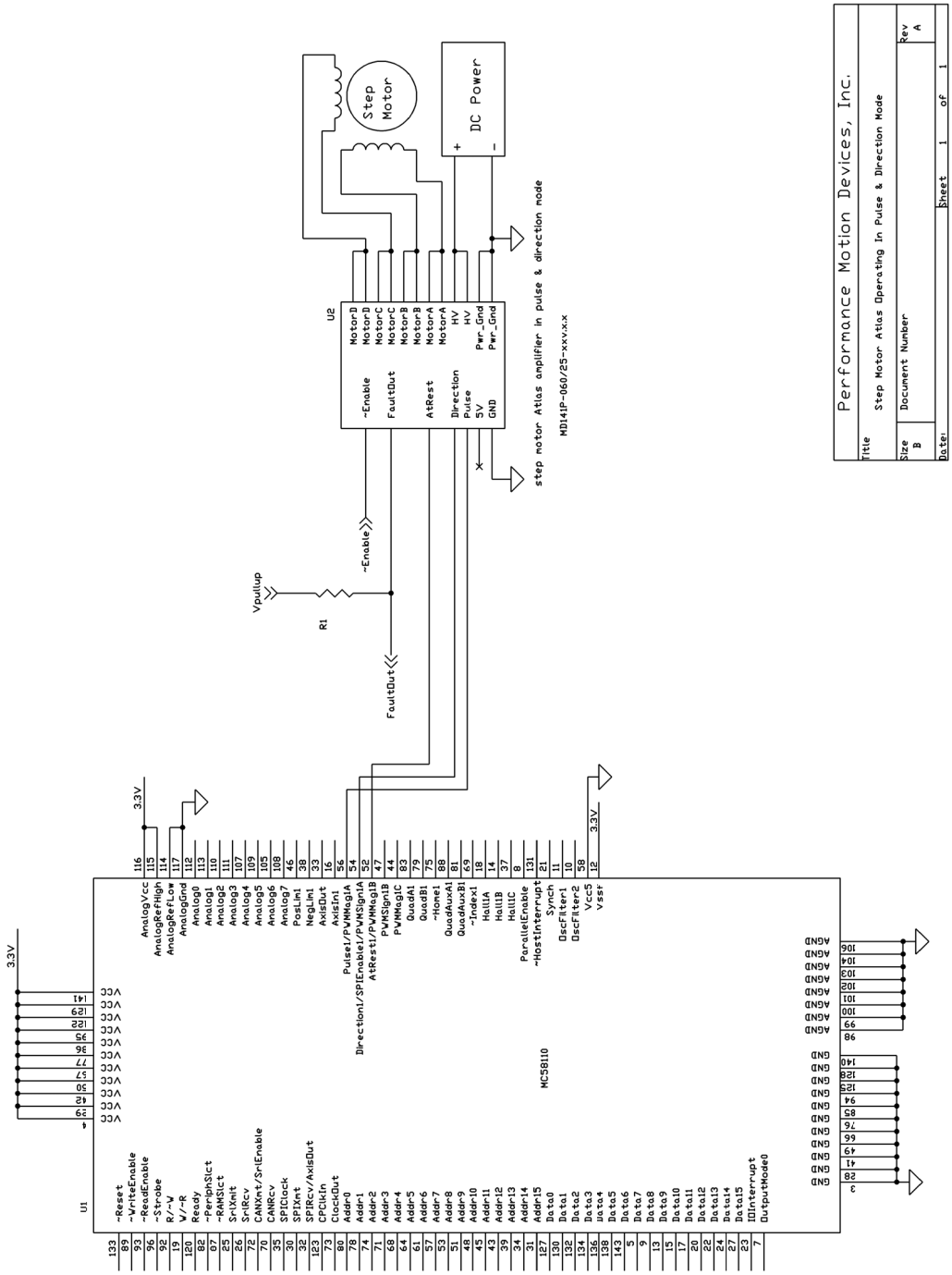

Figure B-3: Step Motor Atlas Operating In Pulse & Direction Mode

B.4 DC Brush Atlas With PIC Microcontroller

The following schematic shows a DC Brush Atlas amplifier connected to a Microchip Technologies' PIC microcontroller. Atlas receives torque commands through the PIC's SPI interface.

A wide variety of microcontrollers, DSP-type devices, or FPGAs supporting SPI interfaces can control Atlas directly. Microchip's dsPIC33FJ64GS606 is used in this example. It supports encoder inputs and other feedback inputs. Users design their own motion control algorithms on the microcontroller, which in turn commands Atlas to drive the motor.

B.4.1 Atlas Power Input and Motor Output

Atlas is powered through pin pairs HV and Pwr_Gnd, and the power source is a transformer-isolated DC power supply.

For DC Brush motors pins MotorA and MotorB are wired to motor windings Motor+ and Motor-, respectively. Pins MotorC and MotorD are left un-connected.

Please refer to B.1 for layout and wiring recommendation on power input and motor outputs.

B.4.2 Atlas SPI Interface

Atlas functions as an SPI slace, receiving control commands from the PIC through its SPI interface. Atlas SPI communication is enabled when ~SPICS is pulled down.

Please refer to B.1 for layout recommendation on SPI interface.

B.4.3 Atlas ~Enable and FaultOut Signals

Atlas has one dedicated input signal, ~Enable, which must be pulled low for the Atlas output stage to be active.

FaultOut is a dedicated output. During normal operation it outputs low. When a fault occurs it will go into a high impedance state. In this example, FaultOut is pulled up by Vpullup through resistor R1. Vpullup can be up to 24V to meet the system requirement. For example, if the fault signal is wired to a 5V TTL input, Vpullup can be 5V.

B.4.4 Microcontroller configuration

In this schematic, the host controller is Microchip's dsPIC33FJ64GS606. The microcontroller's SPI port (SDI1/ SDO1/SCK1) is used for SPI communication.

In this example output pin #12 of U1 (PIC processor) is used to control Atlas' ~SPICS input. ~SPICS has an internal pull-up, therefore, during power up and after reset, the control pin should be in high-impedance or output high state to disable the SPI. Resistor R2 is optional.

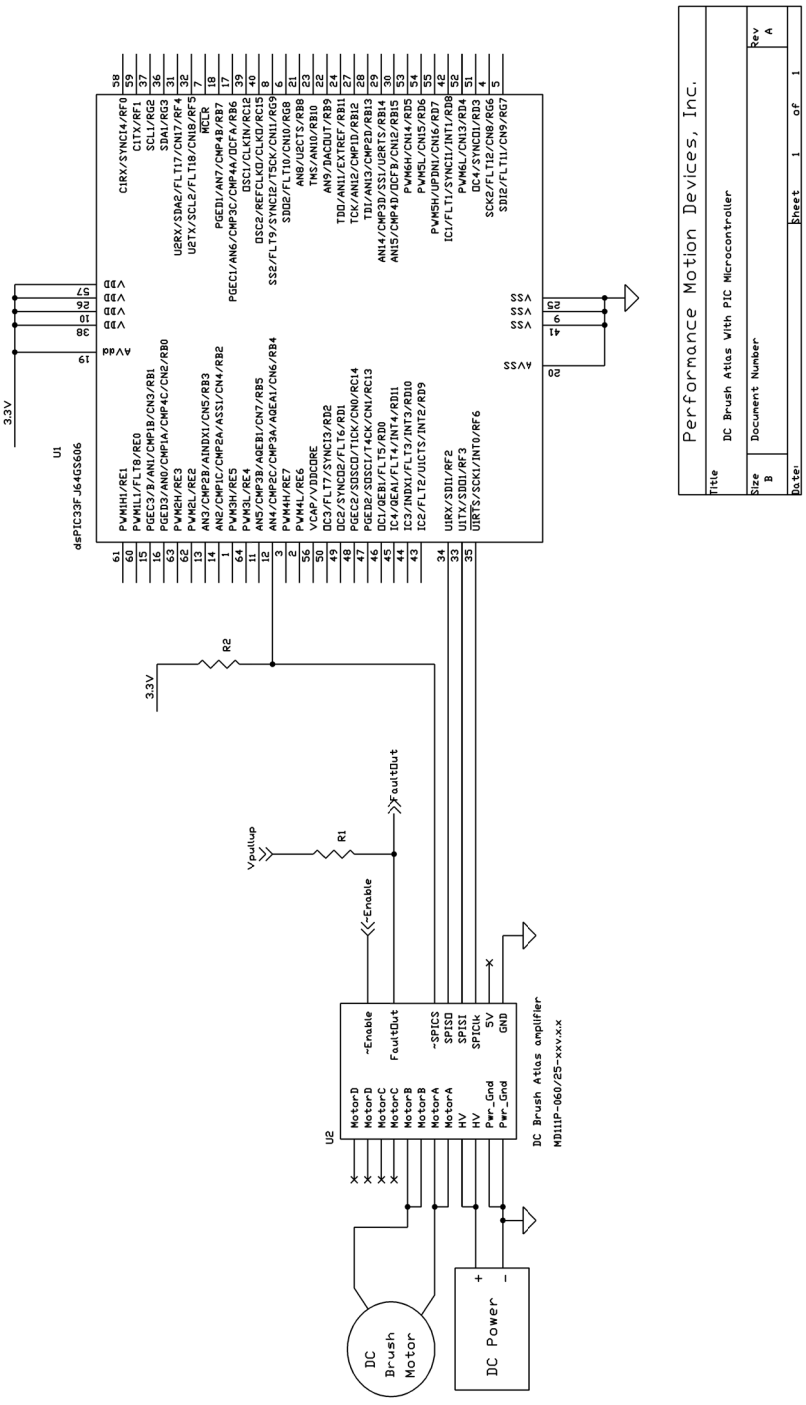

Figure B-4: DC Brush Atlas With PIC Microcontroller

B.5 Step Motor Atlas With ARM Microcontroller

The following schematic shows a step motor Atlas amplifier connected to an STMicroelectronic's ARM microcontroller. Atlas receives torque commands through the ARM's SPI interface.

A wide variety of microcontrollers, DSP-type devices, or FPGAs supporting SPI interfaces can control Atlas directly. STMicroelectronic's STR912FAZ44H6T is used in this example. Users design their own motion control algorithms on the microcontroller, which in turn commands Atlas to drive the motor.

B.5.1 Atlas power input and motor outputs

Atlas is powered through pin pairs HV and Pwr_Gnd, and the power source is a transformer-isolated DC power supply.

For step motors pins MotorA, MotorB, MotorC and MotorD are wired to motor windings A+, A-, B+ and B-, respectively.

Please refer to B.1 for layout and wiring recommendations on power input and motor outputs.

B.5.2 Atlas SPI Interface

Atlas functions as an SPI slace, receiving control commands from the ARM through its SPI interface. Atlas SPI communication is enabled when ~SPICS is pulled down.

Please refer to B.1 for layout recommendation on SPI interface.

B.5.3 Atlas ~Enable and FaultOut Signals

Atlas has one dedicated input signal, ~Enable, which must be pulled low for the Atlas output stage to be active.

FaultOut is a dedicated output. During normal operation it outputs low. When a fault occurs it will go into a high impedance state. In this example, FaultOut is pulled up by Vpullup through resistor R1. Vpullup can be up to 24V to meet the system requirement. For example, if the fault signal is wired to a 5V TTL input, Vpullup can be 5V.

B.5.4 Microcontroller configuration

In this schematic, the host controller is ST's STR912FAZ44H6T. The microcontroller's SPI port is used for SPI communication.

In this example output pin K7 of the U1 (ARM processor) is used to control Atlas' ~SPICS input. ~SPICS has an internal pull-up, therefore, during power up and after reset, the control pin should be in high-impedance or output high state to disable the SPI.

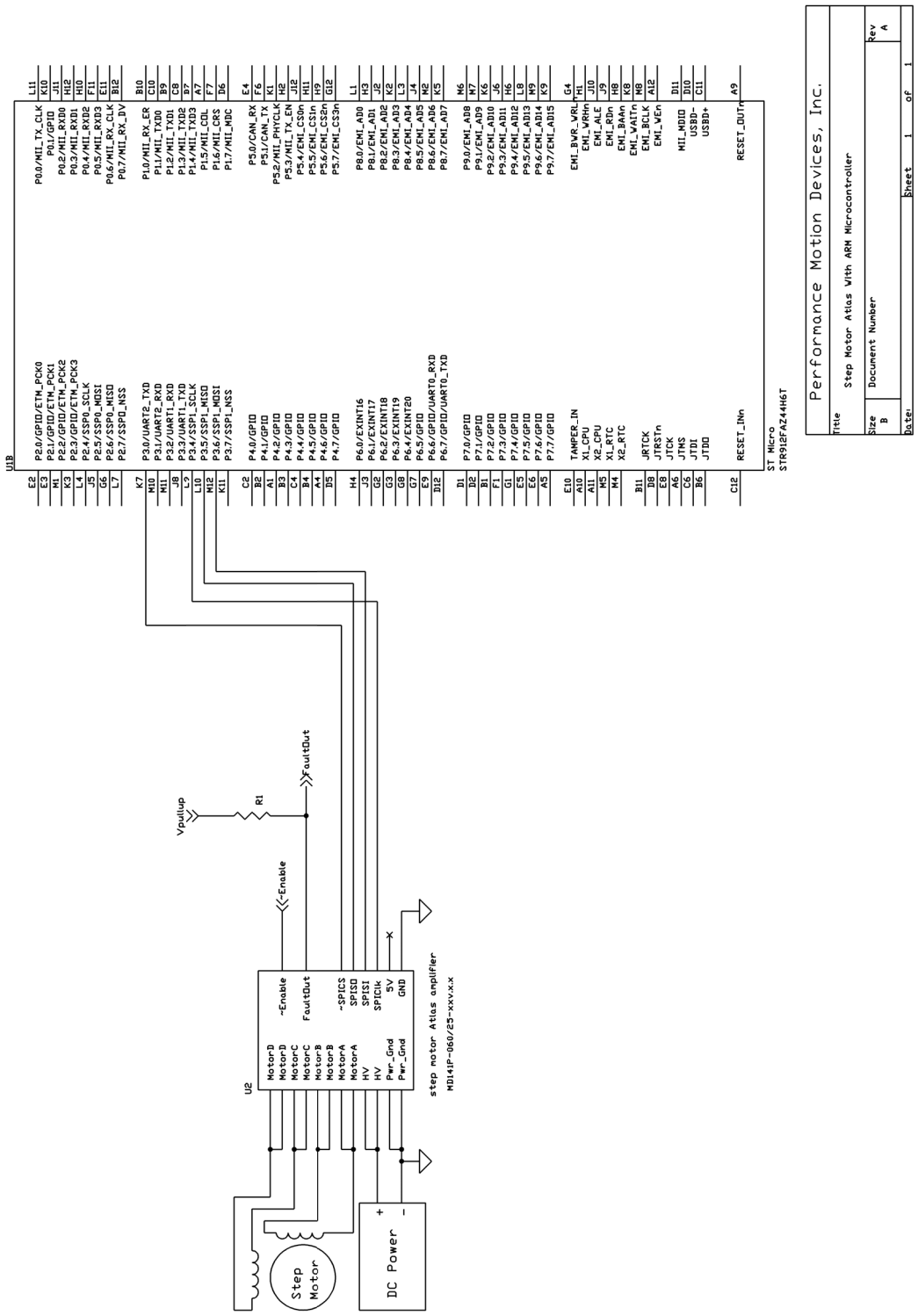

Figure B-5: Step Motor Atlas With ARM Microcontroller

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